Worcester Polytechnic Institute
Digital WPI

Interactive Qualifying Projects (All Years) | Interactive Qualifying Projects

September 2006

Patient tracking in Emergency Department using RFID

Amid Dolatshahi Zand
Worcester Polytechnic Institute

Keet-Fung F. Ng
Worcester Polytechnic Institute

Sweta Suresh Patel
Worcester Polytechnic Institute

Project Number: RAP 4927

PATIENT TRACKING IN EMERGENCY DEPARTMENT USING RFID

An Interactive Qualifying Report

Submitted to the Faculty

Of the

WORCESTER POLYTECHNIC INSITITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Keet-Fung Frankie Ng

Sweta Patel

Amid D. Zand

Date:

Approved:

Prof. Robert Peura, Biomedical Engineering, WPI Major Advisor
Prof. Gregory Volturo, M.D., Department of Emergency Medicine, University of Massachusetts Medical School, Co Advisor

ACKNOWLEDGEMENT

This project could not have been completed without continuous guidance of Prof. Robert Peura, who not only served as our advisor but also encouraged and challenged us throughout our course of this academic program. We are grateful to Dr. Gregory Volturo for providing us technical assistance, and support throughout our project. We would also like to thank Mr. John Pantano and Mr. John McGowens for providing us information for better understanding of the technology and its applications. We also appreciate the help of staff members of Emergency department of UMass Memorial Health Center for their cooperation and help in our observational study.

ABSTRACT

A study was conducted to investigate the implementation of a tracking system for patients in the University of Massachusetts Memorial Health Center Emergency Department (ED). The tracking system would employ radio frequency identification technology (RFID). The RFID tracking system will improve the efficiency and increase the quality of patient care in the ED. The project focused on the return of investment (ROI) for implementing the RFID system. It was shown that the return of investment would be achieved in six months.

TABLE OF CONTENTS

1.0 INTRODUCTION

In contemporary society, there are very few demands that are inelastic. Healthcare happens to be one of them, in which people will visit hospitals or clinics every time there is an illness or injury. It is very difficult for hospital staff to locate their patients, equipment, and even their own colleagues at certain times when they become extremely busy. Physicians need software and technologies that will help them keep better track of their patients, especially in emergency departments where significant movement of patients occurs. This is because patients could be misplaced or simply just wandered off because they became tired of waiting.

Only 3 percent of the 64,000 hospitals in the U.S. have an integrated Hospital Information System (HIS) to manage patients, records and care. Sixty percent of those hospitals with an HIS are using bar code technology to ensure patients receive the right treatment, but limitations in bar code technology still raise issues of intercommunications [1]. This brings up the topic of patient tracking in hospitals, where certain software and technology may be used to help simplify and reduce labor for staff members in the hospital.

The UMass Memorial Health Center Emergency Department Worcester, MA currently uses manual input data entry software called Ibex to keep track of patient location. This is a very useful tool for doctors, as they can look up patient location online. However, the system is prone to errors and is very inconvenient for nurses or other staff to manually input data every time a patient gets relocated. If data is not entered correctly or data is not updated in real time, as it should be, errors may occur that might be hazardous to both the patient and the hospital's reputation, this is especially important in that competition in healthcare is very intense these days. It has been estimated that about 44,000 to 98,000 patients die in U.S. every year due to medical errors [1]. One of many medical errors is the loss of location of a patient. A solution to this problem would be to implement software and technology that can determines the real time location of every hospital patient.

Radio frequency identification, also known as RFID, is a new concept in the world of healthcare. It allows automated tracking of patients by using tags and readers installed throughout the hospital in conjunction with software for patient real time tracking system. To validate this new technology some hospitals and medical institutions conducted RFID trials and projects. Hospitals and health care organizations anticipate that RFID can help save costs and improve patient safety, such as Mass General Hospital in Boston and Emergency Department of the Washington Hospital Center in Washington, D.C. [2] have employed RFID to determine locations of their patients, equipment, and even staff members. Although tagging objects such as medical equipment, drugs and many other objects is a potential area for RFID in hospital, the tagging of patients involves bigger payback with associated increase challenges.

To explore this issue, we conducted a case study that investigated the implementation of RFID technology into the UMass Memorial health center (UMMHC), University Campus Emergency Department. In this project we explored the implementation of RFID technology in the UMMHC Emergency department, which works with the existing Ibex to locate patients in real time. In order to implement this technology, the project focused on the return of investment and the installation of this technology. Contacts were established with companies that provide RFID, such as Radianse Inc, and hospitals that have RFID technology in utilization. After obtaining information dealing mainly with financial savings, studies in the emergency room were also conducted in order to calculate and assume time savings that are an integral part to our final product, the return of investment.

2.0 BACKGROUND OF THE HOSPITAL UMASS MEMORIAL HEALTH CENTER EMERGENCY DEPARTMENT – UNIVERSITY CAMPUS

2.1 FACTS AND FIGURES OF UMMHC – EMERGENCY DEPARTMENT

Gregory Volturo, MD, Associate Director of the Emergency Department (ED) at UMMHC described the facility as a four-story growth tower. The facility consists of ground floor offices, emergency rooms on the first floor, operating rooms and intensive care units on the second floor, and the third floor contains rooms for patients where visitors are able to attend. The ED is 200 ft by 400 ft, which is bigger than a football field. It is divided into a north and south pod; north pod has 14 rooms with 8 beds in the hallway and south pod has 16 rooms with 8 rooms in the hallway. There is an adjacent helipad for life flight helicopters to land.

The ED staff includes 62 physicians and 14 nurses along with 36 residents to care for. According to Dr Volturo, the annual salary of a doctor is approximately $255,000 while the nurses earn about $125,000 including benefits. To earn their high pay, nurses perform significant work, walking 12 miles per shift.

Nurses spend about 10 minutes entering data concerning the location of given patients. Physicians on the other hand, spend up to half their time on the phone looking for staff members and trying to locate their patients, which is by no means efficient. Patient tracking is very difficult when the emergency department has approximately 75,000 patients a year. On busy days they will service over 300 patients and about 170 on slow days.

UMMHC currently uses a non real-time barcode wristband system for patient identification in the hospital. The emergency department uses a tracking system called Ibex (Pulse Check) that is a part of PICIS that requires manual data entry for patient location. In addition to Ibex, another database program called Meditech is also used. Meditech keeps a patient's profile and medication in sequential order. These systems are upgraded by using the Internet and costs around $2,500-3,500 a year to maintain them. However, these systems are not based on real time and require significant labor for manual data entry.

Another technology being used is called VOCERA, also known as 'Voice Recognition Communication Device' which is a portable communicating system used within the emergency department to communicate with or track fellow staff members. Our project evaluates whether the ED should implement RFID technology to track patients, possibly equipment and staff as well.

2.2 CURRENT TECHNOLOGY

2.2.1 Typical procedure for an ER patient

Typically an ED patient either enters the ED by either the front door by himself by ambulance at the ambulance dock. Every patient has to be registered by the greeter before they are sent to triage to categorize their treatment plan. Then, patients are sent to assigned room or to the waiting area depending upon the availability of rooms in ED at that particular time. As soon triage is done their name is removed from the greeter screen and their information is registered into Meditech and also added into the Ibex tracking screen.

Patients brought by ambulance are first transported directly to the ED room and registration goes to them for getting them registered into Meditech system and also Ibex tracking system. Hence there is no need for patients brought by ambulance to go through triage procedures or registration into Ibex greeter screen. During the course of medical treatment, an ER patient may be moved from the ED to another hospital department based on their condition and necessary diagnostic testing or therapeutic procedures. A nurse updates the status of patient being moved from their current location manually into Ibex system every single time a movement occurs. Figure 1 shows a typical scenario of an ER patient's movement when entering an ED.

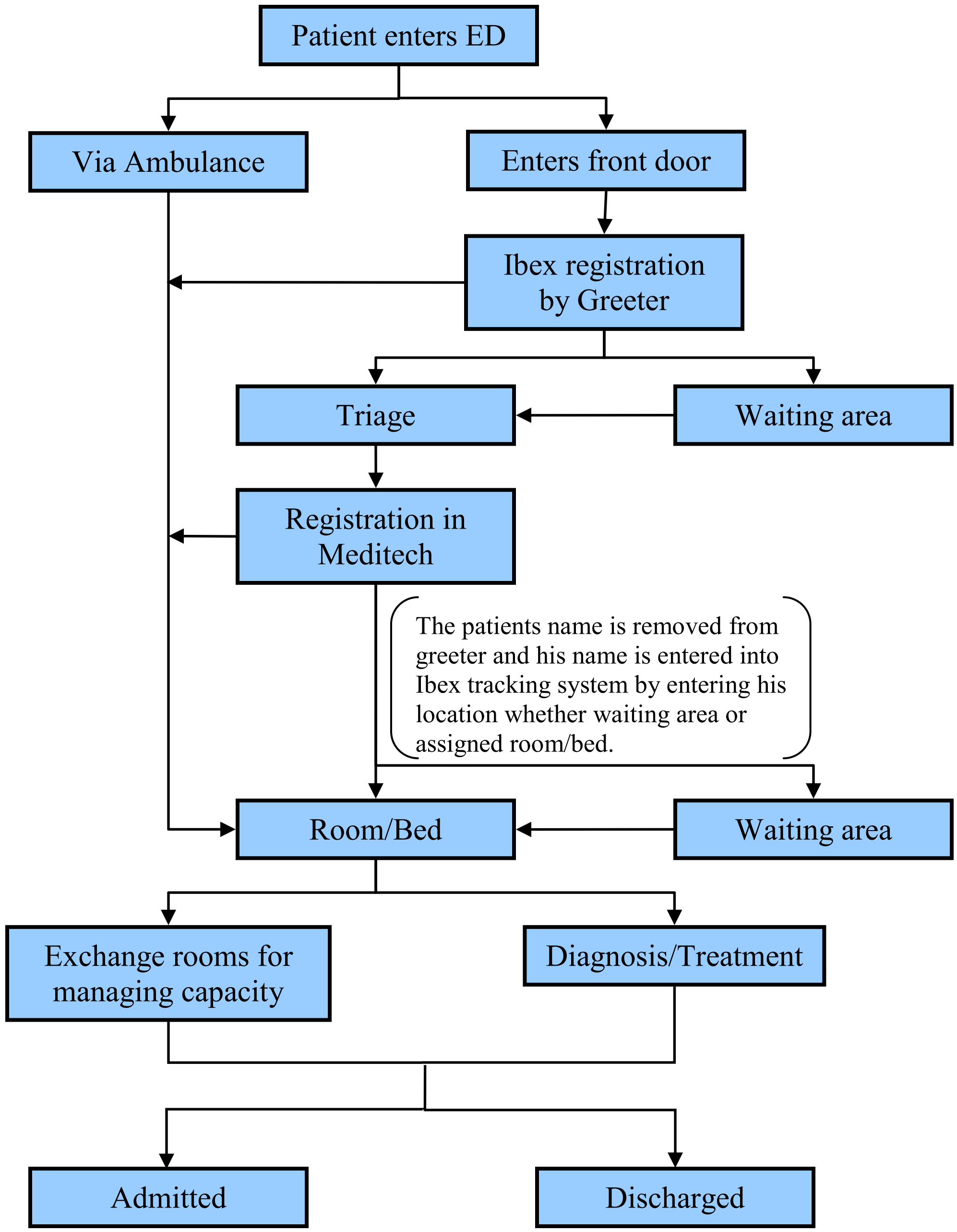


Figure 1: Typical scenario of course of movement of an ER patient in ED

Patient enters the ED either by ambulance or by themselves from the front door. The patient entering from the front door is registered into Ibex greeter and sent to triage or waiting room depending upon the availability. The patient's treatment plan is prioritized in triage and assigned to a room or a hallway bed. Before they are sent to the room, their information is registered in Meditech and removed from greeter of Ibex that is then entered into tracking system. The patients entering by ambulance are directly taken to bed and registration for Meditech is done in their assigned room. All patients are often moved to different departments for diagnosis and treatment during their stay in ED and at end are either admitted for after care and transported to the main hospital or are discharged. Hence for keeping track of patients their status is changed manually into Ibex whenever a movement occurs within ED.

During the course of a patient stay in the ED, the following steps are taken place in order to track and update the status of that patient.

- On entering the ED the patient is registered into the greeter of Ibex.
    - The patient's name, gender, and chief complain is entered onto the Ibex greet screen.
    - They are issued a wristband used as patient identification for their entire visit.
- The patient is asked to wait in the ED waiting area or immediately taken into triage for check up by medical staff to prioritize the treatment plan for the patient.
    - When the patient enters triage, his/her status is changed; the patient is removed from the greeting screen and entered into the Ibex tracking System. Before triage, the patient remains on the greet screen which indicates he is been waiting for triage to be done in waiting area.
    - The results of a patient's triage are entered manually into Ibex.
- After triage the patient is registered into Meditech.
    - Patient's profile into Meditech database system for keeping records.
    - Patient's medications and charts information are entered later into his/her profile in sequential order during his/her course of treatment.
- The patient is then asked to sit in the waiting area or assigned to an ED room depending upon availability.
    - If there are no rooms available then the patient is asked to sit in the waiting area and his/her status is changed manually to wait status.
    - If a room or bed is assigned to that patient, then the status is changed manually to the assigned room and is directed towards his room.
    - The doctor and nurse assigned to that patient are entered into the patient's profile.
- Depending upon the type of treatment required by the patient, he is taken to other hospital departments such as radiology or x-ray rooms for further diagnosis.
    - The status of the patient is changed when the patient enters or leaves their assigned room.

    - When the patient leaves the room his/her location status is updated to the department he/she is taken to for diagnosis or therapeutic procedure.
    - The status of patient diagnosis is entered manually.
- The patient is taken to an operating room if surgery is required or any other type of treatment is performed.
    - When the patient is taken to the operating room the status of the patient is changed to the operating room.
    - Patient status of treatment is updated by manually inputting the data.
- Sometimes during busy times patients are moved around within ED between hall beds and rooms as rooms become available.
    - The status of the patient brought to the hall from room has to be changed and the status of the patient taken to that room has to be updated.
- After the patient treatment, follow on care may be required.
    - Follow ups are arranged for follow on care is entered into the Ibex system.
    - The patient is discharged to a hospital bed taking them out of the ED tracking system. The patient is discharged from ED and entered into system of main hospital.
- If the treatment is completed and the patient is stable, he/she is discharged.
    - The status of patient is changed to discharged and treated.
    - The status of the ED room assigned to patient, who left the ED, is changed to vacant on Ibex tracking screen.

2.2.2 Problems in current patient tracking system

As the patient is being moved, it is important to know where the patient is at all times for the following reasons:

- Any drugs needed to be administered and patient food must be delivered to the actual location of the patient.
- The equipment necessary to perform a procedure or monitor the status of the patient needs to be dispatched to the patient's current location.
- The ED information desk needs to forward calls or direct family members to the patient location.

- In a busy ED, it is important to be sure that a patient is not misplaced while being moved from one location to the other [3].

Tracking patients within UMass Memorial Health Center Emergency Department is done manually through a combination of manual entries within the facilities information systems such as tracking software called Ibex and patient's electronic health records system software called Meditech. This approach places an operational burden on the nursing staff. The system is prone to cause data errors or medical errors. Delays in delivering food and medication to the right patient at the right location may happen, patient medical charts get misplaced and medical equipment sometimes gets lost or misplaced.

Since the input to the current tracking system is manual it takes up significant nurse and staff time, resulting into an inefficient healthcare system. These inefficiencies lead to delays of treatment of patients, which in turn may increase patient waiting time leading to dissatisfaction. For example, if a patient suffered multiple injuries in a car accident such as broken ribs, a fracture in right upper limb, a concussion and an eye injury, he/she may need to be seen by many different specialists such as orthopedic surgeon, a neurosurgeon and an ophthalmologist. In order for the surgeons to locate the patient, they would check the status of patient on Ibex system. If there were delay in entering data into the Ibex the physician would not be able to get the updates about the diagnosis and other information regarding the patient. This may result in treatment delays. In addition, if there are a number of surgeons involved in the treatment, there is a need for real time updates since it is very difficult to communicate with different doctors in a busy ED.

Some ED rooms may be vacant, but their status might not indicate such due to busy periods in ED which is responsible for not utilizing the maximum capacity of an ED. Sometimes the ED patients located in waiting areas may wander around, making it difficult to find them when their turn comes up. Even confusion and patient misidentification may occur such that surgical procedures or incorrect medication is given, as the data entry is not done in real time. These problems are more acute in the ED.

In the section that follows, we propose an approach to improve the operational efficiency of a health care facility, specifically in the ED, through the use of Radio Frequency Identification system. A RFID tag can be embedded in patients ID bracelets, medical charts and medical equipments. RFID system will automatically identify the actual location of a patient and medical equipment. Hence the ED staff workflow will be much more efficient within an integrated health network by using an automated identification or tracking system.

3.0 BACKGROUND OF THE TECHNOLOGY

Radio Frequency Identification (RFID) is one of many Automatic Identification (AID) technologies that have been used for several decades. The origins of RFID can be tracked to World War II, where there was a problem of identifying and tracking planes that could either be enemy or ally. Scottish physicist Sir Robert A. Watson first invented RFID and developed it for radar purposes. During the 1970's, the U.S. government used it for tracking inventory [4, 5]. Since then, RFID has been used in many different fields that range from defense to tracking of weapons, medicine or other goods in the supply chain; paving the way for broad adaptation.

RFID is one of the fastest growing and most beneficial technologies being adopted by business today. RFID might seem simple at first, but it can be difficult to implement successfully. There are different types of RFID systems to consider, while installing and using them to generate data to cut costs or boost efficiency can be challenging. Misconceptions about what RFID is and its functions can pose obstacles that discourage some organizations from taking advantage of the technology.

RFID is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum that uniquely identifies an object. It is a system that transmits and identifies an object or person wirelessly. Data is then exchanged automatically, with no operator intervention required to trigger an RFID read.

3.1 RFID Components:

In general, RFID systems include tags that carry suitable data in transponders and RFID readers along with software to process the radio frequency data emitted by the tag.

3.1.1 RFID Tags:

RFID tags have two basic elements, a chip and an antenna. The chip and antenna are mounted together forms an inlay, which is then encapsulated into other material to finish a tag or label [6, 7]. Tags are usually applied to items that can incorporate an adhesive label or more durable enclosures, such in ID cards or wristbands.

Figure 2: An RFID tag

An antenna and chip are the basic elements of a tag, which is connected by a circuit that includes capacitors and coil (depending upon the type of tag). Proper mounting of these components together forms an inlay of RFID tag that can be encapsulated into another material to form a finished tag. The material used can range from an adhesive label to a laminated case, depending upon its use and the object it has to be attached.

RFID tags vary greatly in performance, including its ability to read or write, along with memory and power requirements. In addition its durability depends upon application and environment. Tags can be made for permanent identification or a reusable purpose, which makes it suitable for lifetime identification or disposable and impermanent identification. The type of packaging used depends on the application, but tag packaging may add cost. The basic feature of a RFID tag is to detect the interrogation field or transmission in order to affect a response for data transfer. The main components in a tag circuitry essentially comprises of the following parts:

1. The antenna and radio frequency receiver and transmission circuit – receive and transmits data forming the bridge of communication between reader and tag
2. State machine or micro-processing circuits are used for control and data management purpose – contains mainly of diode for rectification and switching on the circuit and a capacitor to power up the tag. This approach helps in controlling transmission of data from the chip of tag to the receiver

3. Memory, appropriate to data carrier and functionality needs, stores data related to its application in the chip, typically contains a serial number associated to the tag that can be modified into any type of data depending upon its application.

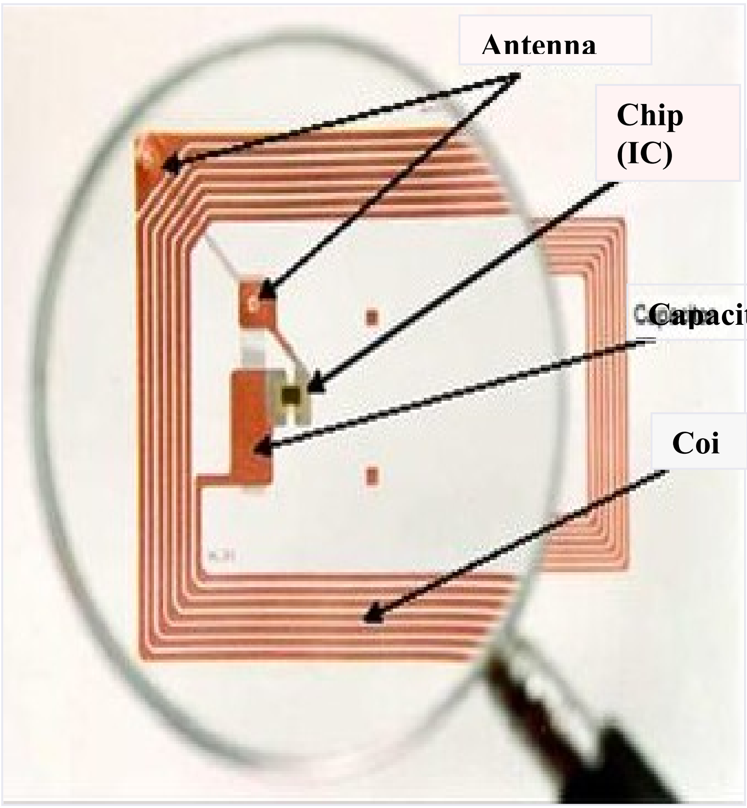


Figure 3a: Inlay of a RFID tag consisting of all the components

Main components of RFID tag consist of an Antenna, memory chip and a processing circuit. Antenna acts as a mode of communication between the reader and the tag. Memory chip can include RAM, ROM or EPROM depending upon its usage. Its function is to store the data and information regarding the product where as the processing circuit is used for control and data management purposes and main parts of its circuit consists of capacitor helping in powering up the circuit and a diode switching the circuit on.

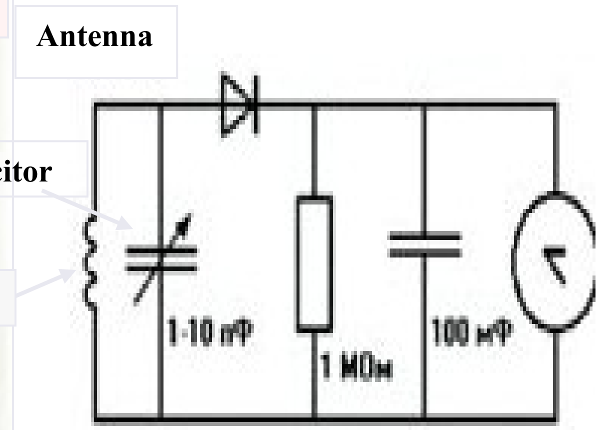


Figure 3b: Detailed circuit that forms inlay of RFID tag

This is an integrated circuit of RFID circuit showing its all-major components. Antenna responds to the signal of the reader by first activating the circuit and transmitting back the data. Antenna forms an integral part of active tag (propagating system) whereas the coil forms the main part of passive tags (inductive systems) for communication between reader and tag. The coil in the circuit is predominantly a part of passive tags as they work on inductive coupling principle of mutual inductance. The capacitor is the part of processing circuit mainly performing the function of powering up the tag hence switching the diode on for transmission of data from the memory chip.

Memory is one of the most important components of a RFID tag. The tag memory may include read-only (ROM), random access (RAM) or non-volatile electronic programmable read-only memory (EPROM) for data storage.

The ROM-based memory is used to accommodate security data and the transponder operating system instructions. ROM is used in conjunction with the processor or processing logic deals with the internal "house-keeping" functions that include delay response timing, data flow control and power supply switching.

The RAM-based memory is used to facilitate temporary data storage during tag interrogation and response. The non-volatile EPROM however, stores the data in the tags that remain inactive for some period to save power such as semi-active tags. The EPROM is used in such tags to ensure that data is retained when is in its quiescent state as it is a non-volatile memory. Power management is an important aspect of this tag feature. Two coupling methods are used to distinguish and categorize RFID systems, one of which is based upon close proximity electromagnetic or inductive coupling and the other is based on propagating electromagnetic waves or propagation coupling. Coupling is via 'antenna' structures, which forms an integral feature in both tag and interrogator (reader/programmer). While the term antenna is considered more appropriate for propagating systems (active tags where battery gives power to the tag), it is also loosely applied to inductive systems (passive tags where power is being supplied from the reader) [14]. Depending upon its power properties tags are divided into three basic types: 1) passive, 2) active, and 3) semi-active.

3.1.1 (a) *Passive tags:* Passive RFID tags have no power source and no transmitter. Passive RFID tags do not require maintenance and can be read in a short range of a few inches to 30 feet maximum [8]. This tag is composed of an inductive coupled tag that comprises an electronic data carrying device, usually a single microchip and a large area coil that function as an 'antenna'. The word 'antenna' is quoted because the 'antenna' for an inductive coupled tag is used for providing power to the microchip during initiation. Inductive coupled tags are almost always operated passively, which means that all the energy needed for the operation of the microchip has to be provided by the reader. For this reason, a passive tag operates at a very short range. Its advantages are its small size and relatively low cost that is very beneficial for many industries. However, it has very short-range capability. The passive tag needs to be close to the reader to be identified and requires the user to move the tagged object near the reader for detection. Passive tags are used in health care for positive identification of small inexpensive items such as some drug dosages, narcotics or other more expensive medications and staff identification.

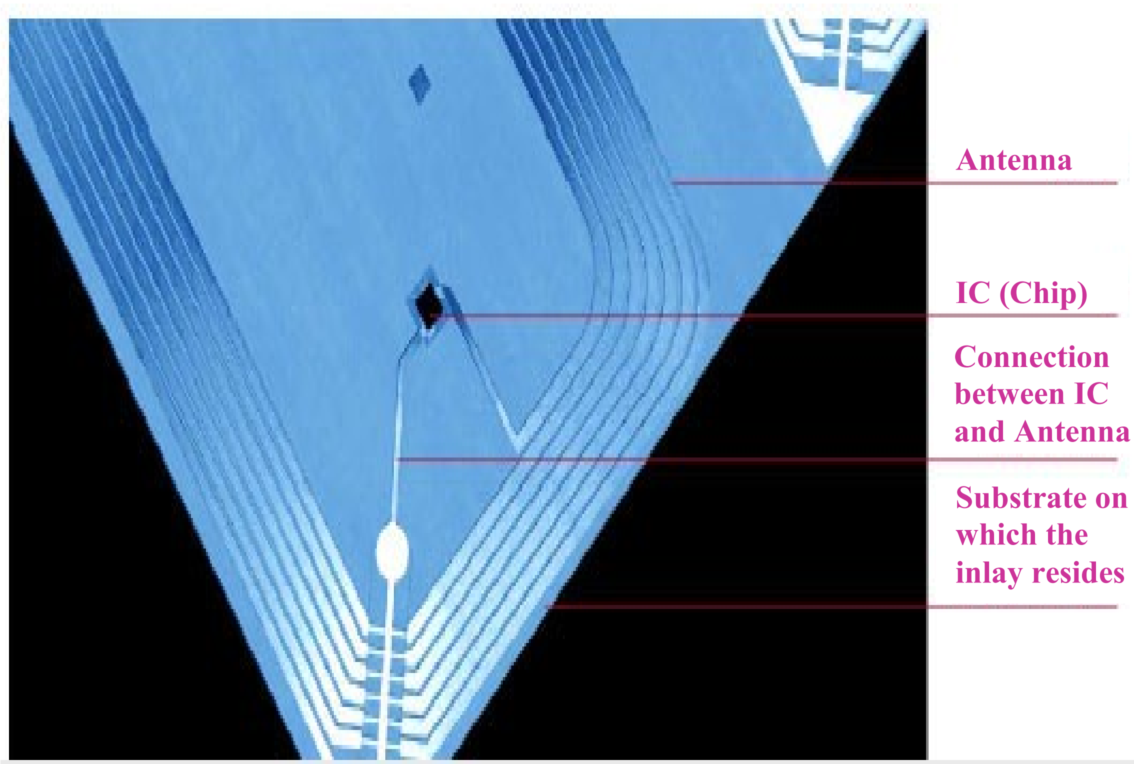


Figure 4: A passive RFID tag

RFID passive tags are read in short range because they do not have any power source or transmitter. It is composed of large area coil which acts as antenna to provide power for microchip initiation to the tag. As they have no power source all the energy for the reader is providing reading data by inductive coupling (mutual inductance between the tag and reader coil). They are cheap and can be inlayed into different types of cheap materials such as stickers that can be applied to almost any type of object because of its small size. But due to its limitation of short range (few inches to maximum of 30 feet) the object it is attached has to be brought near the reader for reading the data.

There are three different types of transponders (passive tags) widely used:

- **Contactless card:**

  This is the most common type of transponder in the market. Their main advantage over other passive tags is their speed, control, and ease of use along with their low cost of maintenance. Modern contactless card inlays are based on a fixed antenna rather than the traditional coil antenna. The advantages of a fixed antenna over a coil antenna are that it is much more reliable, lower cost and has a higher performance. The flexibility of an etched antenna also allows contactless card inlays to be laminated with cheaper materials that cut down the cost of contactless cards by almost thirty percent It is mostly used in mass transit applications, access control and bank security application.

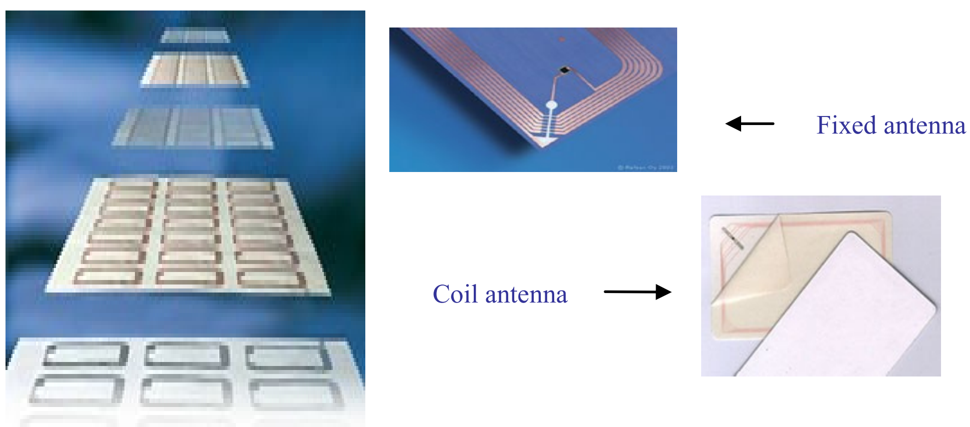


Figure 5: Contactless card

These cards are the most commonly used in transit, access control in banks and other security applications. Modern contactless cards are based on fixed antenna rather than traditional coil antenna. Fixed antenna allows contactless cards to be laminated making it more cheaper and reliable giving higher performance than coil antenna. They are easy to use, have high speed and control and requires low maintenance and hence are most effective where high speed and accurate identification of people are needed.

- **Contactless tickets:**

  Contactless tickets are made of cheaper material; hence the costs are less than the contactless cards and are useful for temporary application. Their main advantage is their disposability, which makes it very convenient for many consumers. Its application is mainly in identification, for giving access control to temporary employee or visitors and in mass transit where single trip tickets are required. Hence it is widely used for giving access to temporary employee/visitor.

Figure 6: Contactless tickets

Contactless tickets are same as Contactless cards except that they are made up of cheaper material making it cheaper than Contactless cards. Their basic advantage is their disposability hence can be used in mass transit where single tickets are required, identification and giving access control to temporary employee or visitor.

- **Smart labels:**

A smart label transponder is a thin, consumable device with a programmable microchip and an antenna. Transponders are embedded inside paper labels or plastic tags to help solve problems in product identification, control, tracking and security and can be used in variety of applications. Smart labels are low cost with a low profile fixed antenna and printed coil antennas contained in a very thin (<0.4mm) flexible substrate [9].

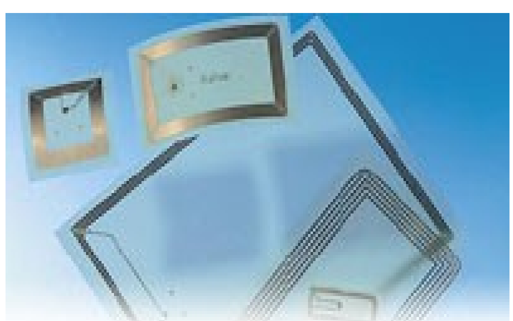


Figure 7: Smart labels

Smart labels are low cost with low profile fixed antenna and a programmable chip. They are inlaid on a very thin (<0.4mm) flexible substrate and can be embedded into plastic or paper labels, hence used in tracking, identification and other security application.

3.1.1(b) *Active tags:* Active tags can operate over a larger range between the RFID tag and the interrogator. Because of this long-range operation, the power supplied by the reader is not sufficient to energize the RFID tag microchip. Therefore, long-range systems require an integral auxiliary tag battery resulting in a much larger tag than the passive RFID tags. This battery does not provide power for data transfer between tag and reader, but serves exclusively to energize the microchip retaining the stored data. Communication between tag and the reader only uses the HF energy received from the reader. The on-board battery supports the prospect for greater range, but with the disadvantage of a more finite tag lifespan compared with passive devices. The active tag is also relatively larger in size and costs more than the passive tags depending upon the application [8, 10].

3.1.1(c) *Semi active tags:* Semi active tags communicate like passive tags but also incorporate a battery. The battery is are not energized all the time. They become active when they receive signal from the reader. This saves battery lifetime but cannot be used for long-range identification, as the signals from readers are distance limited. The range of semi active tags falls between passive and active and their size is comparable to passive tags. The semi active tags are used at checkpoints or toll payments locations as identifiers [10].

Table 1: Comparison of different type of tags

	PASSIVE	ACTIVE	SEMI-ACTIVE
Tag Power Supply	Energy transferred from reader via RF	Internal to tag	Internal to tag
RFID Tag Battery	No	Yes	Yes
Availability of Tag Power	Only within field of reader	Continuous	Only within field of reader
Communication	Short Range (< 9 feet), no communication between tags or readers	Long Range (300+ feet), Networking of tags & readers	Medium Range (<20 feet), Networking of tags & readers
Multi-Tag Collection	Collect hundreds of tags within 9 feet from single reader	Collect 1000's of tags from readers, millions of square feet	Collect hundreds of tags within 20 feet from single reader
Sensor Capability	Read & transfer sensor data only when tag is powered by reader (no date/time stamp)	Continuously monitor and record sensor input with date/time stamp	Read & transfer sensor data only when tag comes into interrogation field of reader with date/time stamp
Data Storage	Small read/write data storage directly on tag	Large read/write data storage directly on tag	Small read/write data storage directly on tag

3.1.2 RFID Readers: A RFID reader is a device used to communicate with RFID tags. Thereafter it provides RF energy to extract information from the tags. For this function, the reader incorporates a decoding section and transmitter/receiver unit. In addition it contains real time processor, operating system, virtual portable memory, some systems are Ethernet compatible in order to communicate with the host computer. The RF transmission/receiver section includes a RFID carrier generator, antenna and tuning circuit. The antenna and its tuning circuit must be properly designed and tuned for the best performance. Data decoding for the received signal is accomplished by use of algorithms to decode the incoming RF signal and communicate with the host computer.

Figure 8: RFID reader

A reader is a device used to communicate with the tag and extract information from it. It also decodest and provides it to the middleware that converts it into readable form. It contains transmitter/receiver unit for transmission of signal and receiving data from tag, decoding unit to decode the data extracted, operating system and Ethernet capability to transmit data to the host computer. It does not need a direct line of sight in order to read a tag hence providing pronounced flexibility to for its placement.

Readers are designed for fast and easy system integration without losing performance, functionality or security. An RFID reader identifies the serial number of the tags that enter into its interrogation zone, that is, the area covered by the magnetic/propagation field generated by the antenna. The size of the interrogation zone depends upon the frequency of the reader. The serial number is put into the integrated circuit of the tag at production stage and consists of several bytes. Readers allow flexibility for placement because direct line of sight is not necessary and read ranges can be extensive. Hence readers can be installed under the floors and mounted on the ceiling. Readers are immune to undesired signals and interference. They have anti-collision and multi tag read capability [7, 11].

3.1.3 RFID Middleware:

Middleware is a generic term used to describe software that resides between the RFID reader and enterprise applications. The RFID Software is a critical component of any RFID system as it receives raw data from the reader and processes it into readable format for the user. Middleware plays a key role in getting the correct information to the right application at the right time. This middleware can be developed according to the application of the system. Other than some basic data software filtering, it can also perform additional functions like monitoring the system status, recording data in databases and other application as required [11].

3.2 RFID SYSTEM OPERATION

RFID technology is based on the concept that the electronic circuit and tag are powered intermittently through radiation from a distance; it can transmit information in air that can be read by a reader located at a distance. In an RFID system, tags are “interrogated” by a reader. The tag reader generates a radio frequency “interrogation” signal that communicates with the tags. The reader also has a receiver that captures a reply signal a tag, and decodes that signal into digital data.

Tags operate differently depending on the frequency of operation. The most commonly used tags are passive tags that operate at low frequency. The reader and the tag are equipped with coils, which are coupled through mutual inductance. The reader coil has an alternating current that produces a magnetic field in its vicinity. This magnetic field, couples with the small tag coil. A diode is used to rectify this coupled coil signal, which charges a capacitor. This capacitor voltage causes the transistor to switch on eventually turns on the IC stored data. The tag then responds by transmitting data from IC back to the reader at a specific frequency, which is then decoded in the reader. The decoded information is then transmitted to the middleware, which translates the data into a readable form for a LAN or WLAN [12].

These passive tags however, have the drawback of limited range. Such near-field communication has some physical limitations. The range can be determined using a magnetic induction approximate of d = c/2πf, where c equals a constant (the speed of light) and f is the frequency.

$$d = \frac{c}{2\pi f}$$ where, d = range of magnetic induction

c = speed of light

f = frequency of operation of tag

Thus, as the frequency of operation increases, the distance over which near-field coupling can operate decreases. A further limitation is the energy available for induction as a function of distance from the reader coil. The magnetic field drops off at a factor of x = 1/r3, where r is the separation of the tag and reader, along a centerline perpendicular to the coil's plane.

$$x = \frac{1}{r^3}$$ where, x = energy from reader to tag (strength of magnetic field)

r = distance between tag and reader

Applications require more memory bits to discrimination between multiple tags in the same locality for a fixed read time. Thus, each tag requires a higher data rate and thus a higher operating frequency, which has led to the design of far field communicating tags [13].

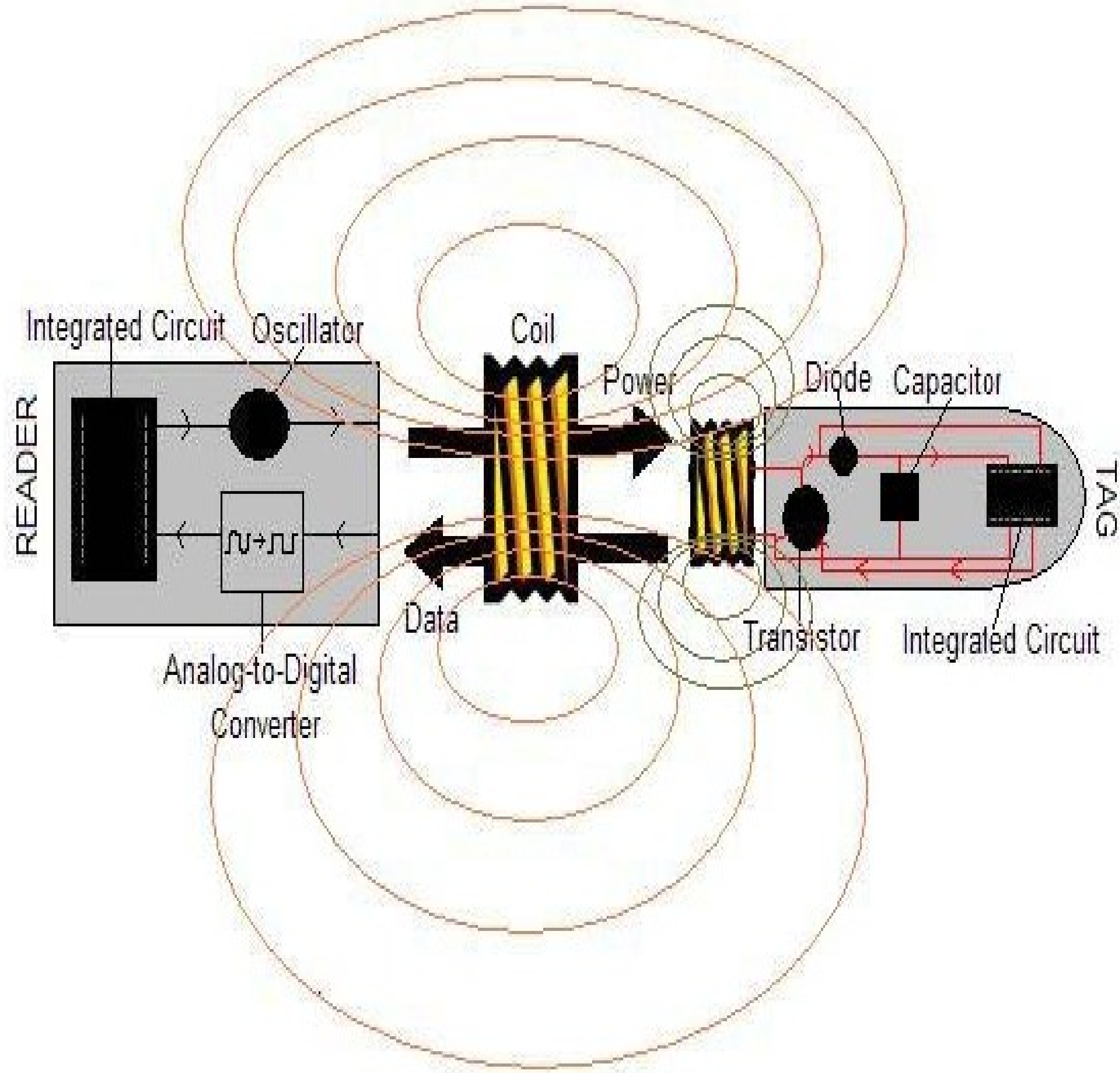


Figure 9: Diagram of power and data flow in passive system

The passive tags are most commonly used for near field communication and operate on low frequencies. They use inductive coupling where the reader and tag communicate with the help of mutual inductance between their coils. The alternating current running through the reader produces magnetic field in the coil that charges up the tag coil and switches on the circuitry inside the tag. The charge from the coil is rectified by the diode and is linked to the capacitor, which will accumulate charge into capacitor powering up its electronics. The transistor is thus then activated turning on the IC. The reader reads the data in form of a specific frequency transmitted by the IC and decodes it. Hence the circuit enables the tag to respond by transmitting data back to the reader which is then processed for decoded data by its integrated circuits.

Active tags operate at higher frequencies. In such systems the RFID tags capture electromagnetic signals propagating from a dipole antenna attached to the reader. A smaller dipole antenna in the tag receives this energy as an alternating potential difference that appears across the arms of the dipole. A diode rectifies this signal and causes a capacitor to be charged.

These tags have a greater range than their lower frequency counterparts and can read a multitude of tags more easily. A far-field system's range is limited by the amount of energy that reaches the tag from the reader and by how sensitive the reader's radio receiver is to the reflected signal. The actual return signal is very small, because it's the result of two attenuations, each based on an inverse square law—the first attenuation occurs as EM waves radiate from the reader to the tag, and the second when reflected waves travel back from the tag to the reader. Thus the returning energy is $y = 1/r^4$ (again, r is the separation of the tag and reader) [12, 13].

$$y = \frac{1}{r^4}$$ where, y = energy returning from tag to reader

r = distance between the tag and reader

Using higher frequency tags in the presence of fluids or metals will result in high signal attenuation in the presence of fluids or metals. This is because at higher frequencies the electromagnetic waves act very much as optical rays, hence non-transparent obstacles attenuate the radio signals traveling through them. Thus, lower frequency technologies are reliable than high frequency counterparts [24].

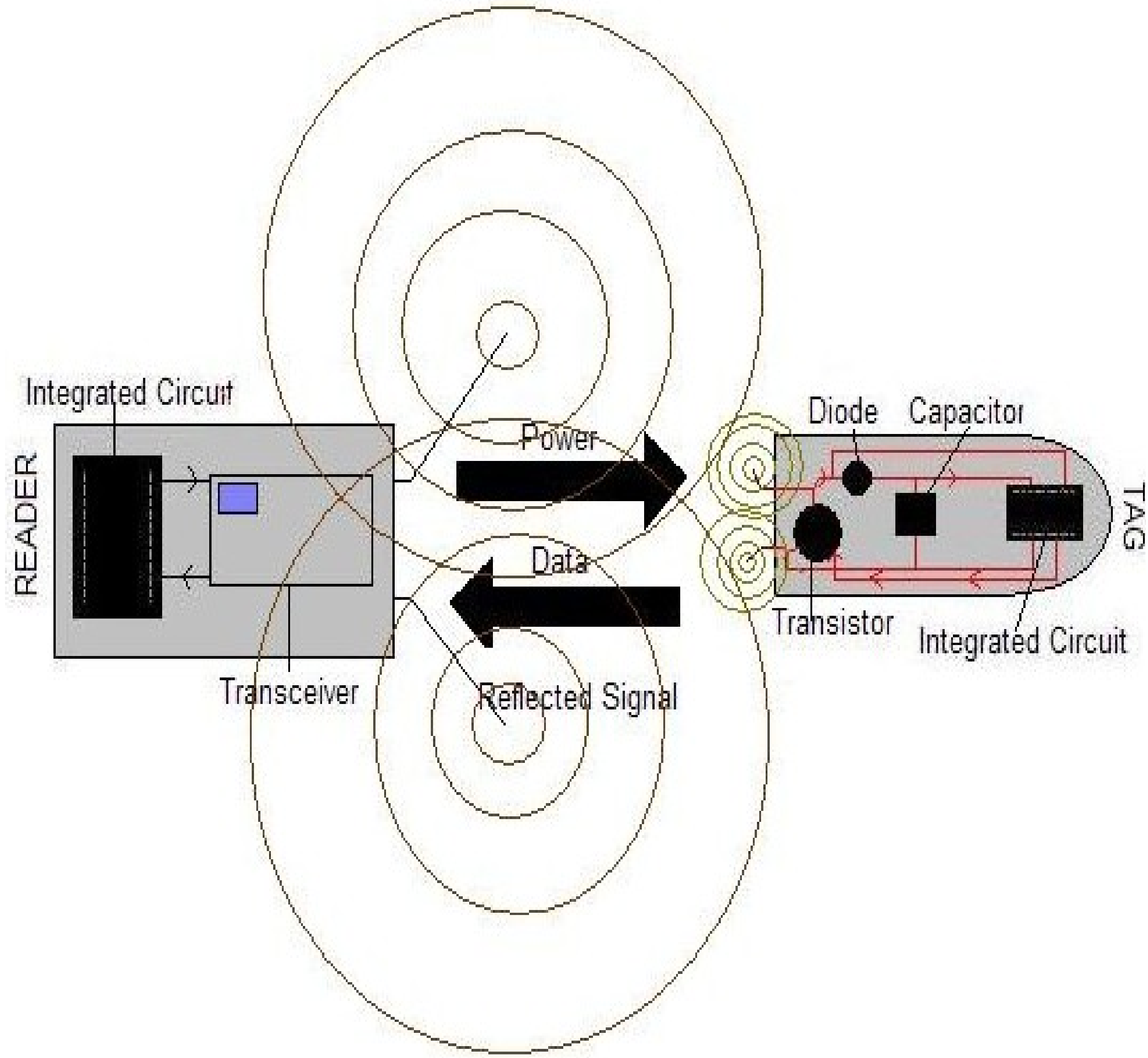


Figure 10: Diagram of power and data flow in an active system

The active tags are used for far field communications and operate at higher frequency. They use propagation coupling where the antennas of both reader and tag communicate by propagating electromagnetic waves. The RFID tags capture electromagnetic signals propagating from a dipole antenna attached to the reader. A smaller dipole antenna in the tag receives this energy as an alternating potential difference that appears across the arms of the dipole. A diode in the circuitry of tag rectifies this potential and links it to a capacitor, which will result in an accumulation of energy in order to power its electronics. This will turn on the transistor eventually turning on the IC for transmission of data to reader in terms of specific frequency.

3.3 CARRIER FREQUENCY OF RFID

The RFID carrier frequency is the leading factor that determines: 1) RFID range, 2) resistance to interference, and 3) performance attributes such as speed of connection and inability to get disconnected. The carrier frequency is an important consideration in both inductive/passive and propagation/active RFID systems. The carrier frequency also provides a convenient classifier for distinguishing the inductive/passive and propagation-based/active divisions of RFID technology and the spectral regulatory constraints that govern their use in different countries of the world.

Table 2 below identifies three major carrier frequencies bands used for RFID for which there is a degree of international harmonization.

Table 2: RFID Carrier Frequency bands

Frequency Band	Characteristics
Low 100-500 kHz	• Short to medium read range (less than 1 foot) • Inexpensive tags (less than a $0.10) • Slow reading speed • Noise sensitive
Intermediate 10-15 MHz (Passive system)	• Short to medium read range (from 10 – 20 feet) • Inexpensive tags ($1 - $2) • Medium reading speed • Not noise sensitive
High 850-950 MHz 2.4-5.8 GHz (Active system)	• Long read range (33 – 334 feet) • High reading speed • Expensive tags ($7 – $85) • Not noise sensitive

The choice of carrier frequency and associated bandwidth of RFID systems and tag design is influence by a number of factors, including:

- Data transfer rate (the higher the carrier frequency the higher the data rate)
- Propagation capability and associated range (the higher the frequency the further the range and higher the power needed)
- Size and cost of transponder construction (the lower the frequency the higher the cost of antenna for inductive/passive systems)

Low frequency inductive/passive RFID tags (100-500 kHz) have a long-standing, well establish application base. Most common in this carrier frequency range is 125 kHz. Heavy-duty tags and associated interrogators (readers/programmers) are available for a wide range of industrial applications where low capacity and low data transfer rate are specified. However, this generation RFID technology is being slowly replaced by a new generation using higher frequency technology due to the fact that it is more advanced.

Intermediate frequency inductive/passive RFID tags (10-15 Mhz) represent the latest and most innovative products in terms of RFID technology. An expanding range of chip-based tags are appearing in the 13.56 Mhz carrier frequency range. The realization of low-cost integrated chip plus antenna structure is favoring devices for a variety of applications. The popularity of 13.56 Mhz is mainly due to the lower cost of tag, higher data transfer rate and higher data storage. Development in both products and standardization are now favoring this frequency range.

High frequency (850-950 MHz and 2.4-5.8 GHz) RFID tags operate in both passive backscatter and active modes. This frequency carrier range has been gaining attention, primarily as a consequence of the higher range capability achievable with passive backscatter technology compared to inductive coupled systems. However, because of the high frequency, power regulation plays an important factor in determining wider use of this RFID technology. These applications include rail trolley identification, road toll management, electronic road pricing systems (ERP) in Singapore and Hong Kong, and also vehicle tracking and logistics real-time location systems (RTLS) [6, 9].

3.4 RFID SYSTEMS

There are four distinguished categories of RFID. A RFID system may consist of two or more of these categories [15]. The four categories are as follows:

- Portable data capture systems
- Networked systems
- Control systems
- Positioning systems

3.4.1 Portable RFID Data Capture Systems:

Portable data capture systems are characterized by the usage of portable data terminals along with integral RFID readers. These systems are used with applications that require flexibility in access with regards to items that are tagged in close range. The handheld readers or portable data terminals will capture data that is then transmitted directly to an information management system, or in other words, the host. This transmission is via a radio frequency data communication (RFDC) link or held for delivery by line-linkage to the host on a batch-processing basis.

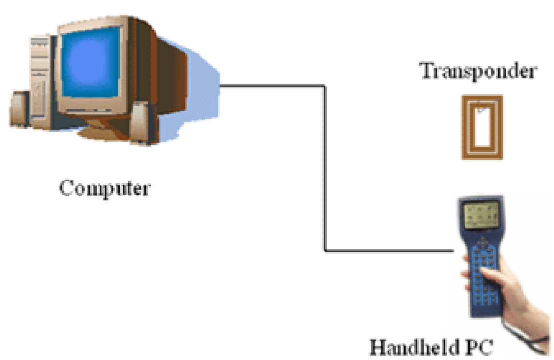


Figure 11: Data communication between a computer and a handheld/portable device

Portable RFID data capture system uses a portable reader or a handheld pc for reading the tags and transmission of the captured data to the host computer or management system. The transmission in this type of system is via Radio frequency signals between the computers and reader (RDFC). This system is used with the applications that require flexibility in access with regard to the items that are tagged.

3.4.2 Networked RFID Systems

Fixed position readers are organized within a given site and also connected directly to a networked information management system. This system can characterize networked systems applications. The RFID tags are placed on certain items or people, depending upon its application.

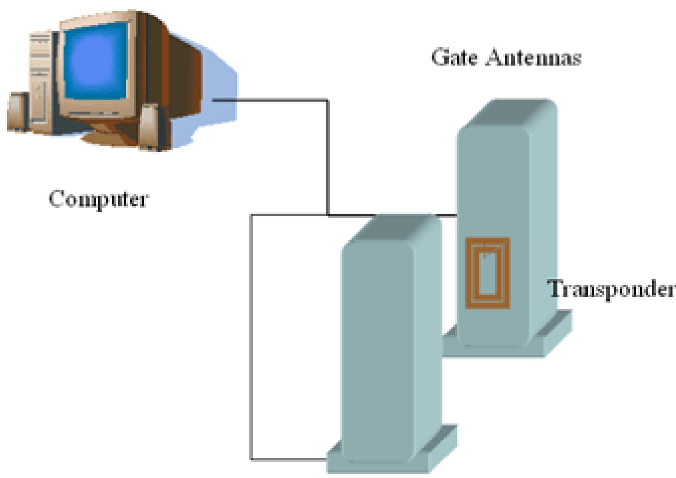


Figure 12: Data communication in a RFID networked system

Networked RFID system has their reader fixed at certain position and are connected directly to a networked information management system, in other words, host computer. This system mainly has its tags on items or people that are mobile and the readers fixed on gate can read these tags as soon as they come into their interrogation zone transmitting the data to network system via wired connections.

3.4.3 Control Systems

Control system applications use tags to start a control function. Typically these control functions include access, sorting and security. This is with respect to automatic barriers, programmable logic control (PLC) sorting, automatic sorting, door entry mechanisms and information systems.

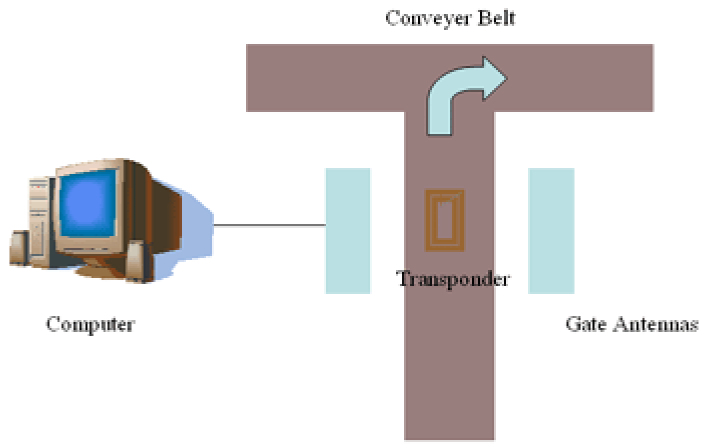


Figure 13: Data communication in a RFID controlled system

Control system applications use tags to start a control function including access, sorting and security. When the reader reads tags, tags control the task of starting or ending as assigned. For example if transponder/tag is read gate antenna/fixed reader then the conveyer belt with start or stop.

3.4.4 Positioning Systems

Positioning systems use tags in order to facilitate automated location and navigation support. These systems often use active RFID tags, where long-range

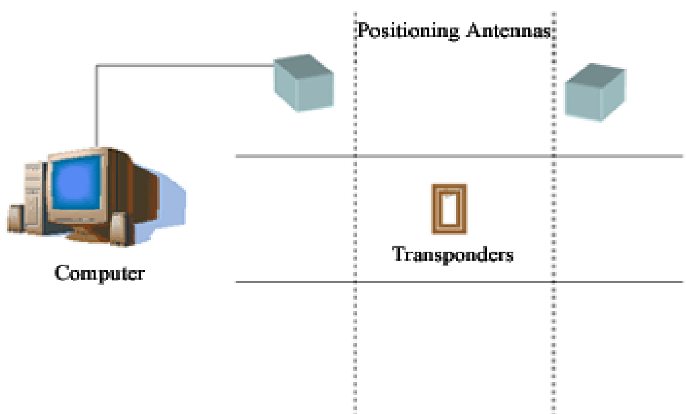


Figure 13: Data communication in a RFID positioning system

Positioning system uses tags in order to facilitate automated locations and tracking support. Readers are installed in a certain area for positioning or tracking of objects that are tagged by active tags. The signals from these tags are read by the reader and transferred to the information system or host computer by wireless communication for identification along with location.

capability to read is preferred. They are positioned on moving objects, such as people or vehicles. The signals from these tags are then tracked by a "grid" of antennas that are mounted and transferred into an information system for identification and location.

3.5 SECURITY AND PRIVACY ISSUES

RFID is an ideal means of tracking the actual locations of people because security is frequently in an area where a premium is placed on preventing problems before they occur. RFID chips are extremely difficult to counterfeit, because a hacker would need specialized knowledge of wireless engineering, encoding algorithm and encryption techniques. Furthermore, different levels of security can be applied to data on the tag, making information readable at some points in the supply chain but not others. Some RFID standards entail additional security.

If an illegal RFID scanner is used to read the tag, then that person can only determine the serial number but no information unless access to the database is granted. RFID tags are also very difficult for consumers to remove. There is a new technology that prints RFID tags on the objects. These tags can be turned off whenever needed and can be read from a distance that overrides privacy problems if used on people [9, 14, 16].

3.6 STANDARDS AND REGULATIONS

Various organizations have an active role in developing standards for RFID systems and are grouped into Industry, National, Regional and International Organizations. At the international level, a major organization that has particular relevance to information and communications technology is the International Organization for Standardization (ISO). Other organizations such as EPCglobal, AIDC and IEEE also develop standards. There are some existing and proposed RFID standards that deal with the air interface protocol (the way tags and readers communicate), data content (the way data is organized or formatted), conformance (ways to test that products meet the standard) and applications (how standards are used on shipping labels, for example). The regulatory system is classified into 5 different classes based on their properties as follows:

• Class 1: a simple, passive, read-only backscatter tags with one-time, field-programmable non-volatile memory.
• Class 2: a passive backscatter tag with up to 65 KB of read-write memory.
• Class 3: a semi-passive backscatter tag, with up to 65 KB read-write memory; essentially, a Class 2 tag with a built-in battery to support increased read range.
• Class 4: an active tag that uses a built-in battery to run the microchip's circuitry and to power a transmitter that broadcasts a signal to a reader.
• Class 5: an active RFID tag that can communicate with other Class 5 tags and/or other devices.

The current standards available are for passive systems. The active system is still in its infancy and hence there are no as such standards available, the companies manufacturing active tags have their own standards. EPC global began developing a second-generation protocol (Gen 2), which was approved in December 2004. RFID vendors that had worked on the ISO UHF standard also worked on Gen 2. All ISO RFID standards have an 8 – bit code that identifies the origin of the data and the tag. Vendors are making product based on the new Gen 2 standard, which paves the way for global adoption of EPC technology in the supply chain [17].

4.0 APPLICATIONS OF RFID

The concept of radio frequency identification has been considered for decades. Previously, it has been too expensive for many consumer applications, thus it has not been used on a frequent basis. RFID technology enables wireless data capture and transaction processing, along with two types of applications, in which one is defined broadly as proximity (short range) and the other as vicinity (long range). Vicinity applications can be described as track and trace applications. However, the technology provides additional functionality and benefits for product authentication.

Proximity applications are typically access control applications. One of the first consumer applications of RFID was the automated toll collection system, which was introduced back in the late 1980s and later caught on in the 1990s. Active transponders are typically placed on a car or truck's windshield. When a car reaches a tollbooth, the reader at the booth sends out a signal that wakes up the transponder on the windshield, which then sends back a unique ID to the reader at the booth. The ID is associated with an account opened by the car owner, who is then billed by the toll authority. Therefore, consumers spend less time fumbling for change or waiting on lines to pay their toll fee.

In the late 1990s, ExxonMobil (also known as Mobil now days) introduced Speed pass, an RFID system that allows drivers who have opened an account to pay for gas automatically. Drivers are given a small and passive 13.56 MHz transponder in a wand or fob that can be placed on a key chain. To pay for gas, they just wave the key fob by a reader built on the gas pump. Seven million people in the United States use the system, and it has increased the number of cars at each gas station since can serve during rush periods at a more efficient pace.

RFID can be used for other consumer applications. One example is recovering lost or stolen items. Toy companies place RFID tags in toys to make them more interactive. When a child brings a toy close to a base station, a reader recognizes the figure and addresses it by name. One area of importance is product recalls, as today, companies often need to recall their items to ensure safety or any other reason. But they can never be sure to recover all items in good condition that were released into the supply chain. With RFID, companies will be able to know exactly what items are bad by tracing through their stores. Customers that register their products could be contacted individually to ensure they know something they bought has been recalled. RFID could also be used in countless other applications, such as airline baggage management, library systems, Rental services, postal and parcel tracking services among many others. Whether smart appliances with RFID readers catch on depends on how long it takes for the RFID tags to be price efficient. It may also depend on whether consumers find RFID enabled products to be convenient enough to accept the potential invasion of privacy that comes with having RFID tags with their products. But RFID will certainly have a positive impact on our society in a less direct way as many of the consumer applications and benefits of RFID are still several years away [9,18].

4.1 NEED FOR TRACKING IN HOSPITAL ENVIRONMENT

People in a hospital, regardless of a staff member or patient, are always changing their location and may need to be tracked. Doctors, nurses and patients may be needed in case of emergencies. Equipment also needs to be prevented from being stolen. The correct medicine must be given to the right patients along with the right amount at the right time. Thus all the above factors affect the standard of patient care in the hospitals in order to improve management [12].

4.1.1. People:

RFID tracking may be used to locate patients, staff and infants.

4.1.1 (a) *Patient tracking*: Patient identification and real-time location assistance are often needed to ensure patient safety, especially when urgent medical attention is needed. In high utilization departments such as the ED, streamlined patient flow and related resource utilization are critical to efficiency and quality. The consequences of a sub-optimal patient flow may include delays, overcrowding, diversions and related financial losses. Safety is also a concern in healthcare facilities, where there is a likelihood of patients getting lost or temporarily misplaced. Certain patient populations in particular, such as children, the elderly, those with Alzheimer's, psychiatric conditions or mild dementia present higher risks. According to the Healthcare Advisory Beard, hospitals in the United States lose 4 – 5 % of their total revenues due to poor patient management. Tagging patients also enables positive identification when delivering medication or when performing surgery [19]. This approach can reduce medical errors, this is important considering that between 44,000 and 98,000 patients die in the United States each year from medically related errors [1].

4.1.1 (b) *Staff tracking:* Staff tracking does more than just locate the right person when needed. Valuable human resources such as nurses and other staff members are not always allocated properly, which may add cost. When hospitals are able to track clinical staff, this also helps identify bottlenecks and adapt workflow for better resource allocation.

4.1.1 (c) *Newborn babies:* Each year, a significant number of newborn babies are stolen from hospitals. In addition, there are a few errors when matching babies with their parents. Putting a RFID tag on each baby will help track their location in the hospital on a real-time basis, as well as accurately who they are. RFID tags are best placed on newborn's ankle.

4.1.2 Equipment

4.1.2 (a) *Medical instruments tracking:* Most healthcare organizations struggle with the management of their clinical equipment such as infusion pumps, EKGs, ventilators, portable x-ray machines, gurneys and wheelchairs. Often nurses sacrifice precious time looking after patients to look for equipment instead, thus leading to many unsatisfied patients. Hospitals then end up purchasing or renting additional equipment to ensure quality of care is not impacted. Biomedical engineering teams spend a great deal of time finding equipment that must undergo preventive maintenance to ensure regulatory compliance. Healthcare organizations report that 15 – 20 % of their assets are missing [19]. It is estimated that theft of equipment and supplies costs hospitals $4,000 each year along with over 975,000 staffed beds in the United States. This represents a potential loss of $3.9 billion annually [20]. If each of these instruments used a RFID tag system for real-time tracking, not only can theft be prevented, but also the equipment could be located easily in times of emergencies.

4.1.2 (b) *Surgical tools:* After an operation, surgeons fear that a surgical tool being left inside the patient's body by accident. Having a small RFID tag on each of the tools will enable the doctor to track each and every piece of equipment, which would eliminate this occurance. The doctor can fully concentrate on the operation itself.

4.1.3 Medicines and Drugs

The Food and Drug Administration (FDA) estimated that up to 40 percent of medicines shipped from countries such as Argentina, Colombia, and Mexico may be counterfeit [21]. Clearly counterfeit drugs are a huge problem to our society and should be eliminated. RFID is believed to be the best way to deter counterfeit drugs, since RFID tags located on the packages would include specific information required by the laws of the different states or countries. The required information will be contained in the RFID tags would reduce counterfeits significantly.

5.0 ADVANTAGES OVER OTHER IDENTIFICATION SYSTEMS

A RFID system allows the wireless storage and automatic retrieval of data. It provides a significant improvement over, not only conventional identification along with tracking and stocking of objects, but also a barcode system as well. Barcodes can only be read in “line of sight”. RFID does not need “line of light”. The use of RFID is expected to help boost the supply chain efficiency, improve security, cut down on theft and counterfeiting, increase asset visibility, enhance inventory control, and automate stock replenishment along with many other improvements.

Overall, RFID technologies have been found to be more reliable and durable than barcodes in various applications and functions. Furthermore, RFID technologies offer a broader wireless means than bar codes for information collection and tracker to track and identify between objects where the information is communicated electronically via radio waves.

Those fundamental properties eliminate manual data entry and introduce productivity even under difficult working environments; along with the reduction labor, eliminates human error, and also puts a lot of data on your fingertips. Barcodes have other shortcomings as well. If a barcode label is ripped or soiled or has fallen off, there is no way to scan the item. Standard bar codes identify only the manufacturer and product, not the unique item. In addition, the technology of RFID tags is hard to counterfeit and reproduce which ensure a higher security protection [9].

Table 3: Comparison between Barcode and RFID system

System	Barcode	RFID
Data Transmission	Optical	Electromagnetic
Typical Data Volume Data Modification	1-100 Bytes Not possible	128-8K Bytes Possible
Position of Data Carrier for Read/Write	Visual contact	Non line of sight possible
Reading Distance	Several metres (line of sight)	From centimeters to meters (depending on the frequency and tags)
Access Security	Little	High
Environmental Susceptibility	Dirt	Very small
Anticollision	Not possible	Possible

6.0 EXAMPLES OF HOSPITALS USING RFID

In the current market there are various companies that develop an ultra-wideband RFID system for healthcare facilities. Amongst them are very few companies that provide this system for patient tracking. These companies include Radianse Inc. based in Lawrence, Massachusetts, Aeroscout based in San Mateo, California and Exavera Technologies Inc. based in Portsmouth, New Hampshire. These companies offer RFID tracking system in collaboration with tracking software companies like Picis Inc., Cisco Systems Inc., and Parco Wireless respectively. Some of the hospitals this technology is listed in Table 4.

Table 4: Examples of hospitals using RFID technology for tracking

(P – Patient Tracking, S – Staff Tracking, E – Equipment Tracking)

		Apps			
Hospital	**Since**	**P**	**S**	**E**	**Comments**
Mass General	1/03	X	X	X	Covers perioperative care for 50 OR unit
Helsinki Univ	11/03	X	X		Covers ED, OR, ICU & 3 wards
Hannibal Regional	5/04	X			Cover perioperative care
Hosp at Univ of Penn	10/04			X	Covers perioperative, will cover patient in ED
Mississippi Baptist	9/04	X			Covers perioperative care
St. Vincent's (AL)	9/04	X			Capacity management hospital-wide
Brigham & Women's	11/04			X	Covers 10 cardiac units, ORs, Cath
Lancaster General	11/04	X			Covers perioperative care
Harrisburg Hospital	1/05	X	X	X	Currently installing hospital-wide
Community General	1/05	X			Covers Perioperative care
Ascension/Kaiser	5/05		X		Various nursing units
Yale – New Haven	5/05	X	X	X	Covers CTICU and perioperative care
Atlanticare	6/05	X	X		Covers ED
GI Center of Mid-South	8/05	X			Covers surgi-center
Erie County Medical Center	3/06	X			Covers perioperative care
Legacy Health - Portland	4/06	X			Capacity management hospital-wide

P= patient location, S = staff location, E = equipment tracking

7.0 METHODOLOGY

The application of RFID to medical services is in an emerging stage. It is appropriate to adopt an explanatory case study approach. For our study, data collection involved establishing a case study database consisting of archival records, meeting minutes, surveys and other relevant material. Meetings were arranged with Dr Volturo, Vice Chairman of UMMHC – Emergency Medicine, which was held on a weekly basis for studying the current situation of Emergency Department of UMMHC. This in formation involved the current technology used for tracking and other relevant facts and figures. We also met with Mr. John Pantano, Vice President of Sales and Marketing Radianse Inc. (Appendix-2) for values involving installation cost and utilization cost of the RFID tracking system. Next, we developed open-ended questions focusing on the development and the implementation process of the project for some of the hospitals that already use this technology. We received information regarding Mass General Hospital, Boston from Mr. John McGowens (Appendix-5) who had observed the hospital and interviewed Mass General Hospital officers. The meetings and interview information was then transcribed. We took notes during and after the all interviews and visits. We conducted observational studies in UMMHC ED to learn how the ED operates; problems encountered everyday, flow of work, staff and patients. We determined the amount of time being utilized to manually input the data into the Ibex tracking system every time there is a change of status for a patient (Appendix-4).

8.0 RFID TRACKING SYSTEM IN UMMHC

8.1 ISSUES WITH USING THE RFID TRACKING SYSTEM

Introducing an emerging technology into any organization is challenging, especially into hospitals. It is expected that such projects exhibit innovativeness and applicability. Despite having many advantages, problems may arise while using RFID technology.

8.1.1 Budget Constraints

One of the main reasons that many hospitals do not implement and take advantage of RFID technology is because of its expense. In today's market, it is expensive to install this technology as well as purchase complimentary components such as tags, receivers, software, and associated RFID staff training. In addition to this, RFID tags may be lost or misplaced easily, which results in additional costs for hospitals.

8.1.2 Loss of tags

It is estimated that hospitals that are currently using RFID technology lose 20% of their tags each year during daily hospital operations. This is in accordance to our meetings with John Pantano and John McGowens. Losses of tags are the result of human error or situations beyond one's control.

Misplacement of the RFID tag is the most common reason for losses. For example, a RFID tag may be removed from a patient during a surgery and placed on the bed sheet. While the bed sheet is being removed for laundry, the RFID tag may also be washed. As a result, the RFID tag is no longer functional and is destroyed. Misplacement of RFID tags in hazardous areas is also a common feature. During surgery, a RFID tag might end up in disposable areas such as used syringes, needles, and trash areas where because of biohazards no one can retrieve the tag for reuse. Other possible mistakes in misplacement may simply be to fail to recollect tags from patients. However, if the ED is set up to detect RFID tags at the exits, this should be less of a problem.

RFID tags may also malfunction and not be used anymore. As mentioned, they may end up in laundry machines where the circuitry will be destroyed. Also, RFID tags are impacted by humidity, as they cannot withstand extreme temperatures and hot environments. These are the main causes of malfunctioning of RFID tags, although it is not common.

The losses of tags are best prevented through careful and good management. For example, staff members such as nurses and staff should be trained to collect patient tags before any potential losses or possible malfunction occurs.

8.1.3 Infection Issues

With regards to the hospital environment, tracking patients with reusable tags may carry the risk of transmitting infectious diseases or germs from one patient to the other. This will result in transmission of illness, causing disability, and even death to certain individuals. Such transmittable infections include HIV/AIDS, diarrheal diseases, tuberculosis and measles, which are particularly tragic to the individuals who are already under treatment in the hospital for other purposes.

8.1.4 Interface problems and bugs

As mentioned above, the current patient tracking system at UMMHC Emergency Department is not a real-time system. Although RFID solves this problem, there are costs involved in the development of hardware and software interface systems. In relation to the software system, there could be software viruses and threats. This is unfortunate because, when new technology becomes available, businesses are not the only interested parties, but also civil liberty groups and hackers.

Civil liberty groups mainly focus on people's privacy and are concerned that RFID technology may cause invasion of privacy. RFID tags can enable certain individuals to obtain data from profiles without approval or even knowledge. For example, RFID-enabled public transit tickets may allow public transit managers to accumulate a record of a person's travels in the past year, with information that may be of interest to the police, divorce lawyers, and others. In the case of hospitals, hackers may also obtain a patient's profile that includes their medical history, allergies, and confidential information. However, this situation is very rare because a hacker must have an immense amount of education regarding wireless engineering, encoding algorithm, encryption techniques and the institution that he or she is trying to hack, which makes it very difficult [22].

It may also be difficult to locate a certain patient, since the ED rooms are 130 square feet and the walls do not appreciably block radio frequency transmission. The RFID tags have a range of 30 feet each, so if the rooms are located next to each other, it becomes difficult to locate the actual room that the patient is in.

8.2 SOLUTION TO THE PROBLEMS

As seen already in the previous section, there are various issues involving the installation of RFID technology in the ED. To overcome these issues, we came up with some achievable solutions and additional plans pertaining to the development strategy of the application of RFID, device and data management of the components.

8.2.1 Development strategy

The main issue regarding the use of disposable tags instead of reusable tags is that the costs of tags contribute system cost that is of primary concern. Disposable tags are very expensive and be a major consideration when considering the budget constraints of the hospital, but will be beneficial when considering the prospect of losing tags and infection issues. On the other hand, using reusable tags will solve the total system cost, but will raise a question of loss and malfunction. Good management of RFID devices helps prevent loss and malfunction of reusable tags.

Developing a strategy of using an equipped tag sterilization station inside the hospital, which prevents infection between patients and staffs, can solve the infection issue. Employees need to be fully trained to systematically decontaminate used tags by washing. This process primarily includes cleaning tags by using disinfecting wipes after the tag is retrieved before using it for another patient. Thus, such a procedure will guarantee patient safety even though the same tag is used for different patients. The wipes used for cleaning are inexpensive. Purchasing a limited number of reusable tags per year will contribute greatly in reducing the investment as compared to investment using disposable tags.

Another appealing solution that omits sterilization is reusable tags that use disposable plastic covers. The cover can be thrown away after each application, while the electronic chip is saved and placed into a new cover for the next patient. This solution will dramatically decrease the risk of disease infection from one patient to the other and will lower the cost of sterilization. On the other hand, a large number of inexpensive covers will need to be purchased every year. It will also require the staff to be more educated to handle the chip replacement that may slightly increase the total cost of using this tracking system. Though this strategy is appealing, it is yet not available from Radianse because it is still in the process of development. It is very likely that such reusable tag with a disposable cover will be available in the market in the near future.

8.2.2 Device management

There must to be a balance between the requirements of the RFID components and the initial invested. For example, disposable tags will reduce work and concerns regarding the misplacement and malfunction of reusable tags, it will cost much more, and thus the investment would be higher. Managing devices at an efficient level will solve both issues of losing tags and budget constraints regarding components and thus there is no need for purchasing extra tags or readers.

The main functions of RFID are data collection and transmission. For subsequent data processing and generation of information for decision-making, the readers should be carefully mapped in the area where the patients are tracked. An inefficient plan of installation will cause unnecessary purchase of extra readers, which will not only increase the cost of the investment, but will also affect data collection resulting in unreliable readings. The number of readers and its location are cautiously mapped on the floor plan (Appendix) in the ED at UMMHC successfully to avoid extra readers cost. When plotting the readers on the map of the floor plan of the ED, we determined that an approximation that 91 readers are needed to cover entire area for successful data collection. In our calculations, we also considered rooms with lead walls that will not allow RF signal to pass through. Each of these locations were given their own reader for data collection. After analyzing the ED floor plan we concluded that there would not be any dead zones present where readers would not be able to detect tags.

Reduction in percentage of lost or misplacement and malfunction of tags can be achieved by regulating some procedures such as retrieving tags from patients as soon as they are discharged. Readers placed near exits and can be connected to an alarm system so when a patient tries to leave without returning the tag, the alarm will sound and the security can retrieve the tag back. This prevents any reusable tags from leaving the ED. Procedures should be created such that there will be a minimal number of chances that the staff might forget to take off or misplace the reusable tag causing a loss to laundry or any hazardous area.

8.2.3 Data management

There are usually issues with locating patients between two adjacent rooms because of the differentiation of the RFID system compared to the size of ED rooms. This problem is addressed by the use of algorithms. Hence the system must be careful configured such that the correct position of patient is determined without any confusion. This is achieved by configuring the software with developed algorithms that calculate the distance of the tag from the reader. The location and the path of the moving or stationary person with the tag can be calculated based on the signal strength, which is sensed by more than one reader [2] that alleviate the difficulty of positioning patients that are located in hallway beds or in any two rooms that have thin walls.

The system offered by Radianse solves this problem because their system combines infrared and radio frequency transmission for managing data of the location of patient. Infrared rays cannot pass through walls whereas radio frequency waves can and do not require a line of sight for collection of data. Therefore, the reader in the room reads the data tags in that room only and not the ones in next room that solves the position location problem in two adjacent rooms.

Handling a large amount of data is not of a big concern. According to a peer-reviewed study conducted at Mass General Hospital in 2003, it has been proved that this system can track a very large number of patients with 100% accuracy. For managing the data after installation, the system has various rules that are regulated for data transmission between different devices or systems. For example, the transmission between tags and readers, readers and databases, also databases and detection systems (software) for correct data information updates. In the emergency department, when a patient is moved from an ED room to a X-ray room for a very short period of time, the Ibex system will show the room status as vacant creating misunderstandings and resulting in overloading of ED. Hence a rule has to be regulated such that the tracking systems should display the assigned room on hold to avoid confusion. Other decisions for include whether or not data should be stored or not and if stored, how long depending upon the rules of the ED also has to made. Applying all of these data management factors, there will be substantial reduction of data to be handled, while resulting in meaningful information for decision-making.

8.3 COST OF RFID SYSTEM

One of the main concerns with using an automatic identification system such as RFID is the cost of implementing and maintaining the system. The costs include the tags, readers and the system interface. However, there are unexpected costs that come into play only after the installation.

In this section, we will estimate the total cost of employing RFID tracking system in UMMHC, Emergency Department for the first five years. The installation cost is counted as part of first year costs. In order to achieve this objective, the cost of a number of items needed to be determined.

8.3.1 Installation Cost

I. Tags:

For the purpose of tracking patients in the ED, both disposable and reusable RFID tags can be used. The unit price for a reusable tag is $30 while a disposable tag costs $9.75.

Figure 14a: Reusable active RFID tags

These are active tags provided by Radianse Inc. that can be easily clipped on patients clothes.

Figure 14b: Reusable active RFID wrist band

The active RFID wrist bands manufactured by Radianse Inc. can be easily worn on wrist by patients.

Knowing the fact that the average number of patients visiting the ED is 235 per day, we can easily calculate the cost of purchasing either type of tags.

3.1.1 (a) Disposable tags: The yearly cost of disposable tags is a function of the total number of patient visits to the ED twste cost of the tags.

Total Cost = (Unit price of the tag)*(Average number of patients) …… (equation 8.1)

Cost per day : $\$9.75 \times 235 = \$2{,}291$

Cost per year: $365 \times \$2{,}291 = \$836{,}215$

3.1.1 (b) Reusable tags: Reusable tags need to be sterilized after each use and will remain attached to the patient for usually no more than one day in the ED. Therefore, there has to be an amount of tags in reserve for situations when tags cleaned for the next patient. We assume that 470 tags, twice as much as the number of daily patients would be a reasonable number of tags needed for the ED. Normally the first 235 tags will be used in the first day and the next 235 for the following day. Meanwhile the initial first day of the tags will be sterilized for the day after.

Total Cost = (unit price of the tag)*(twice the number of patients) (equation8.2)

Cost: $\$30 \times 470 = \$14{,}100$

It is reasonable to assume that a fraction of the reusable tags will malfunction or simply get lost every year. We assume a rate of 20% of tags needed to be replaced or bought per year.

Annual Maintenance Cost = 0.2 * (Total Cost) (equation 8.3)

Cost: $0.2 * \$14{,}100 = \$2820$

Table 5: Comparison between the cost of reusable and disposable tags for the first three years

	Reusable	Disposable
Unit Price($)	$30	$9.75
1st year cost	$14,100	$836,215
2nd year cost	$2,820	$836,215
3rd year cost	$2,820	$836,215
Total Cost in 3 years	$19,740	$2,508,645

Figure 15 demonstrates the huge gap between the price of reusable and disposable tags.

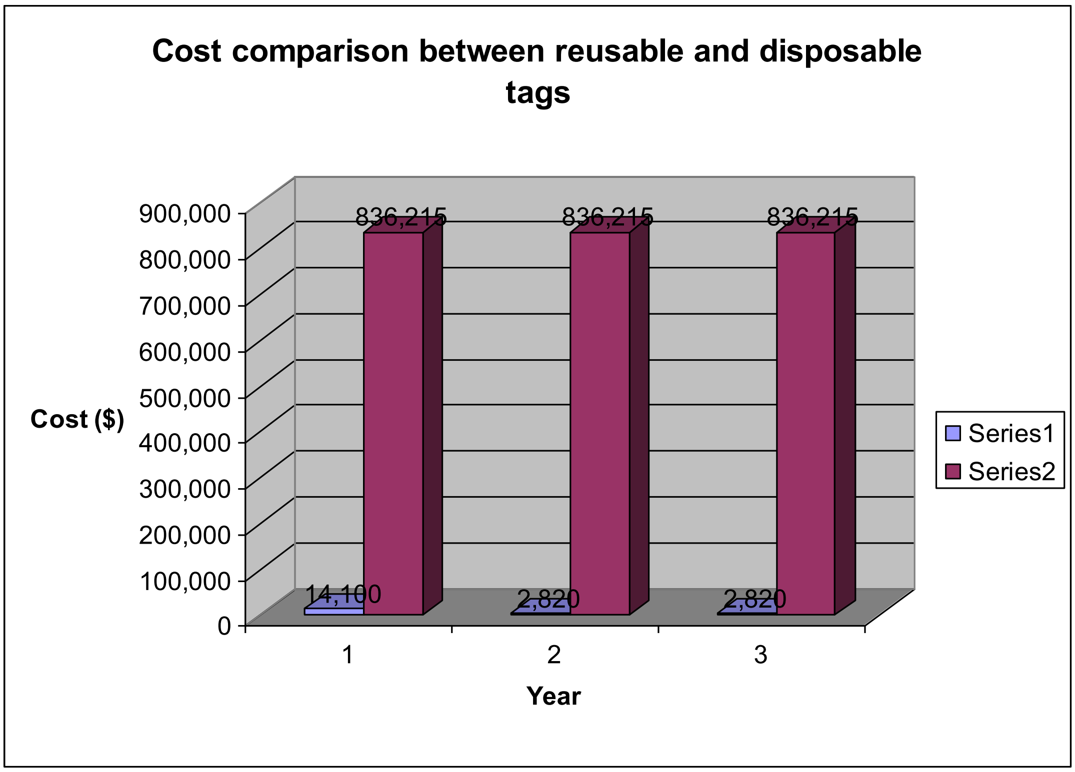


Figure 15: Cost comparison between reusable and disposable tags. The huge cost the disposable tags drives us towards the use of reusable tags.

By looking at the figure, it is easy to conclude that the use of reusable tags is significantly less expensive than disposable tags.

II. Receiver:

An adequate number of receivers must be installed in the ED. In this case and accordance to John Pantano and John McGowens, 91 receivers would be needed to cover the entire ED floorplan. A detailed map of the ED floor with the accurate location of each receiver and its range of coverage is provided in the Appendix-3 of this report. After installing the 91 receivers, there will be no dead zones in the ED floor. It is worth nothing that the rooms with lead walls, which block the radio frequency propagation, are provided with their own readers. The unit price of a Receiver is $350. The cost of readers is calculated to be $31,850.

Total Cost = (unit price of the receiver)*(number of receivers) **(equation8.4)**

Cost: $350 \times 91 = \$31,850$

Figure 16: LAN ready readers

Readers manufactured by Radianse Inc. uses LAN for transmission of data after being read from the tag. As it uses LAN, reader doesn’t need any power source of its own because LAN acts as power source for the reader.

III. <u>System Interface, Server PC:</u>

Besides the cost of tags and readers, installing the System Interface costs $10,000, which is a one-time charge. The current tracking system, Ibex must interact with the new system, which can be done by the RFID provider for no cost.

The Server PC which processes the data received by receivers costs $4000. Either a Wi-Fi system or a Local Area Network (LAN) can be used to transfer data to the server. For our case in the emergency room, a LAN system is preferred. A reader requires power supply for its function which would not be provide by a Wi-Fi system while LAN acts itself as power source so there is no need for an external power supply if LAN is used. Hence, the cost of providing power for each receiver can be prevented. The cost of putting each LAN tap into service is about $1000. 91 taps are required since there are 91 readers but the cost involved in pulling out LAN for each reader would be much less than the estimated cost because every single room in ED has a LAN tap already which will ease the process of installing readers.

IV. <u>Other costs:</u>

When the system is installed, staff members need to be trained in the use of this new system. Therefore, there is a cost to train the staff. The training cost depends on the application and the time needed to train them.

For extra security in the hospital 4 security alarms should be installed at the ED exit doors. These alarms will go off if a patient tries to leave the ED with the tag on.

The total cost of installation is summarized at the table below, which again the quantity and price are in accordance to Mr. John Pantano and verified by Dr. Greg Volturo.

Table 6 : Cost of installing RFID system in UMMHC

Cost of RFID Installation				
Item		Unit Price ($)	Quantity	Cost($)
A	Reusable Tags	30	470	14,100
B	Receivers	350	91	31,850
C	System Interface	10,000	1	10,000
D	Interaction with Ibex	0	1	0
E	LAN Taps cost + Infection control	300+700	91	91,000
F	Implementation and Configuration	(A +B + C) * 15%	1	8,077
G	Server PC (Dell, IBM)	4000	1	4,000
H	Staff Training	Depending on Application	Hours needed to train staff	
I	Exit security Alarms	2,000	4	8,000
		Total Cost		**167,027**

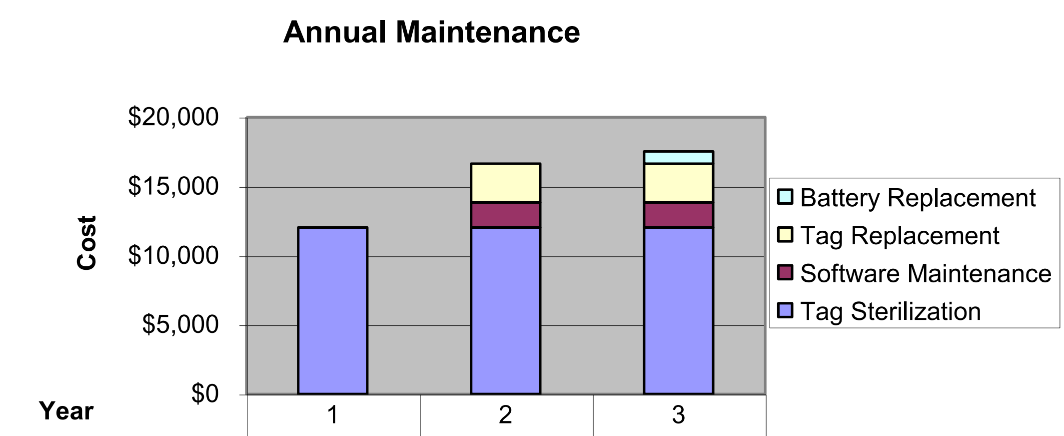
8.3.2 Annual maintenance cost

The cost of tag cleaning comes into the calculations. It is estimated that employees would spend 2 hours every day to clean about 235 tags. The salary is estimated to be around $12 per hour, which totals to $12,024 for a year. The other cost is maintaining the software. Software support contract costs $1,800 a year. Batteries need to be replaced every other year. The cost of labor and purchasing 470 new batteries will be $660 per year.

Finally, we assume that 20% of tags (94 tags) will be lost every year, which adds an amount of $2,820 to each year's total cost. The additional maintenance cost of RFID is summarized in the following chart and graph.

Table 7: Annual maintenance cost of RFID tracking system after installation

Annual Maintenance Costs			
Year 1 (after RFID Installation)			
Cost	**Item/Service**	**Price/Wage ($)**	**Quantity**
A	Tag cleaning	$12/hour + 37.27%	2 Hours/Day
B	Software Support Contract	1,800/year	1
Total Cost (Year 1) = (A*365)+B = $12,024 + $1800 = <u>$13,824</u>			
Year 2			
A	Tag cleaning	$12/hour + 37.27%	2 Hours/Day
B	Software Support Contract	1,800/year	1
C	Lost and malfunction of tags (20%)	30	94
Total Cost (Year 2) =(A*365) + B + C =$12,024 + $1,800 + $2,820 = <u>$16,644</u>			
Year 3			
A	Tag cleaning	$12/hour + 37.27%	2 Hours/Day
B	Software Support Contract	1,800/year	1
C	Lost and malfction of tags (20%)	30	94
D	Battery Replacement	0.46	470
E	Labor for C	$20/hour	1 day
Total Cost (Year 3) =(A * 365) + B + C = 12,024 + 1,800 + 2,820 + 216 + 660= <u>$17,520</u>			
Assumption: Lose or malfunction 20% of tags each year			



Year	1	2	3
Battery Replacement	$0	$0	$876
Tag Replacement	$0	$2,820	$2,820
Software Maintenance	$0	$1,800	$1,800
Tag Sterilization	$12,024	$12,024	$12,024

Figure 17 : Expenditure required for maintenance of RFID tracking system every year

Hence the total expenditure for the proposed tracking system every year would be detailed in table 8.

Table 8: Total cost for employing RFID tracking system for UMMHC, ED

Year	Expenditure Description	Total Cost
1	Installation cost + annual maintenance (includes only tag sterilization)	$179,051
2	Annual maintenance	$16,644
3	Annual maintenance (includes battery replacement cost)	$17,520
4	Annual maintenance	$16,644
5	Annual maintenance (includes battery replacement cost)	$17,250

In summary, in this section we have compared the cost of installing RFID technology as well as the cost of maintaining this technology. We have also projected the usage of reusable tags as opposed to disposable ones, as the cost range is much to great if compared annually. In the next section, we will consider the return of investment (ROI) for the University of Massachusetts Medical Health Center Emergency Department if they choose to implement this proposed system of RFID technology.

9.0 RETURN OF INVESTMENT (ROI)

9.1 OVERVIEW OF ROI

Return of investment is a comparison between the money earned or lost in a venture to the amount of money invested. It is basically defined as the benefits achieved through an investment. This is the main issue when deciding on whether to make investments in a healthcare or any organization. The return of investment that this project deals with is the RFID tracking system. A portion of the investment is made in creating the infrastructure and the remainder is made for its application.

In our case, the emergency department at UMass Memorial Health Center is considering an investment in RFID to track patients real-time. It is proposed to build an RFID infrastructure to support this application. System infrastructure investments such as installing readers and purchasing patient tags will provide long-term resources for an organization that constitute a foundation for present and future applications. It is anticipated that this system will generate an increase in satisfaction for patients as well as staff. The benefits of an investment are may be indirect and pay long-term returns. In contrast, applications generate direct and immediate value. The ROI is found within applications, not the infrastructure. The infrastructure provides a means to transmit and store data, while applications leverage data to generate a considerable value. Not all the benefits are quantitative and cannot be estimated or expressed in currency figures. Hence the returns can be classified into "Qualitative returns" and "Quantitative returns" [23].

Qualitative returns: Qualitative returns are intangible and valuable and do not necessarily justify the purchase. They may only increase the benefits within the organization. These returns include the satisfaction of patients and the staff members of the hospital. This is measured as a major return considering nursing labor disputes that took place at St Vincent's hospital in Worcester, MA. In 2000, nurses at St Vincent's hospital went on strike, not because of salary issues; rather their issue was that their excessive workload compromised of patient care. They were consistently required to work overtime, as much as two shifts (16 hours) continuously without the nurses being able to refuse.

One way to reduce nursing time is to introduce labor saving technology. Labor savings can be considered as an important way to increase the satisfaction of the staff members at the hospital. A RFID tracking system would then increase staff satisfaction. With a RFID system it would provide labor savings and automated updates patient status in real time. This directly affects the workflow decreasing the waiting time of patients, which results in increased patient satisfaction. This is one of the keys to improving the standard of patient care of any hospital.

Another important factor is efficient hospital bed capacity management. An efficient workflow depends on the availability of rooms in hospital. Thus, higher occupancy rates would occur. This would decrease the waiting time of the patients, which will not disappoint them. Hence the qualitative returns are indirect benefits that result in an increased return of investment.

Quantitative returns: Quantitative returns are returns that are tangible and can justify the purchase of the RFID system, as they are objectively easy to measure and provide a value to the actual return. Increasing revenue is the key factor of the return of investment. Increase in revenue will result due to the decrease in the amount of patients who are left without being seen (LWBS). Some ED patients leave the hospital for a number of reasons, one of which includes getting tired up of waiting before being actually treated, or also not getting effective service because of unavailability of nurses or other staff members. With the RFID tracking system, it is anticipated that there will be a reduction in the time needed by each nurse to manually input patient data and status with a RFID tracking system. The nurse time saving contributes to ROI. This in turn will help in all the qualitative returns mentioned earlier. On the other hand, qualitative returns such as patient satisfaction will help reduce those patients LWBS and increase the number of returning patients. After an efficient visit, patients may feel that the hospital has a standard of patient care is good or excellent. They will most likely return to the same hospital if they need treatment again in the future. This undoubtedly will increase the revenue of the hospital.

Hence, we can see that a large number of quantitative returns directly affect qualitative returns, which will increase the return of investment due to the installation and use of a RFID tracking system at the UMMHC ED.

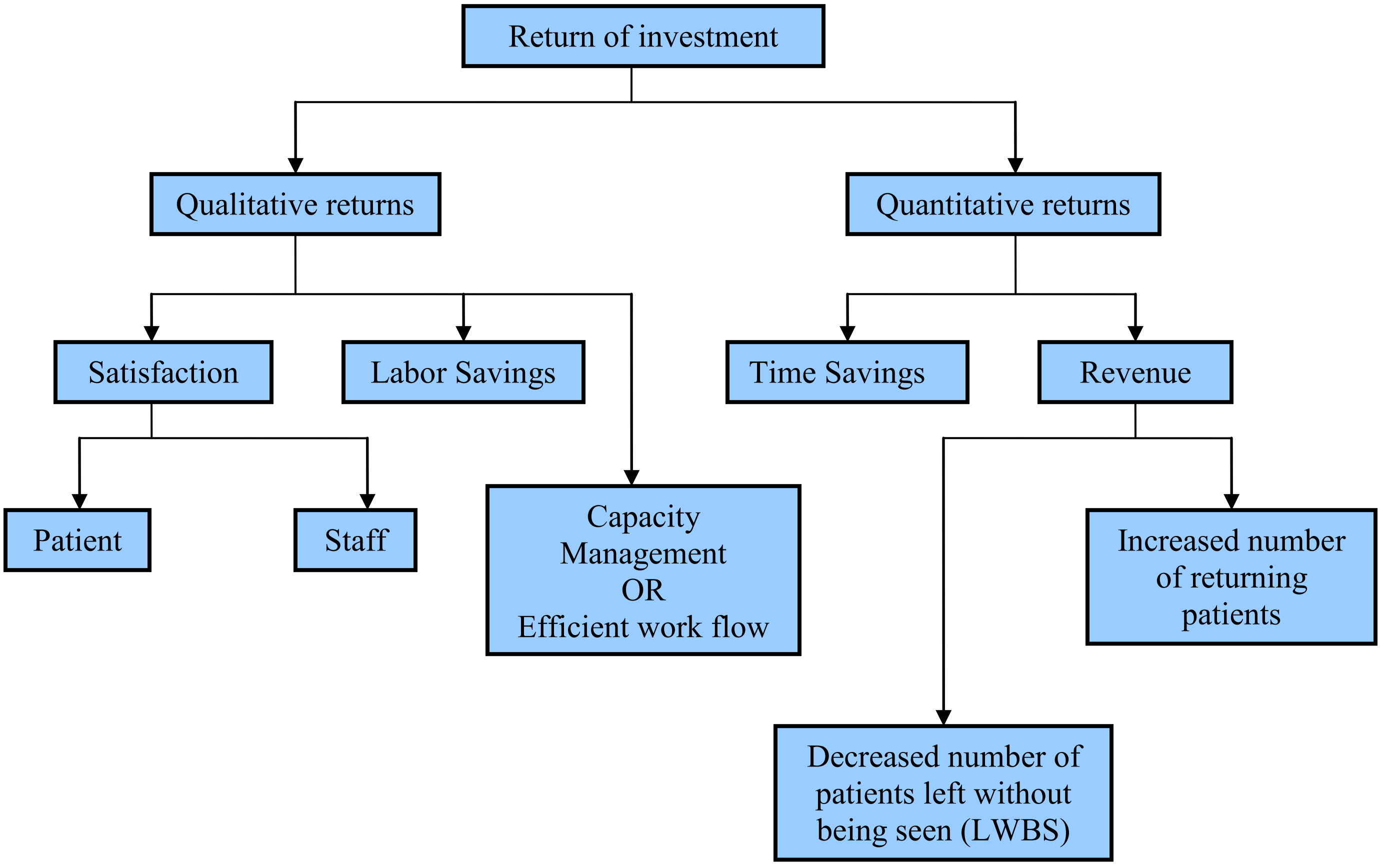


Figure 18: Major factors serving to the Return of investment of RFID tracking system

[Figure 18: Return of Investment of RFID tracking system can be classified into two categories qualitative and quantitative returns. Qualitative returns are the returns that are intangible and valuable but cannot necessarily justify purchase where as quantitative returns are tangible and measurable and can justify purchase as it provides actual value in form of money to the return. Satisfaction of patients and staff, Labor savings of staff and capacity management that is efficient work flow can be considered as qualitative return. Whereas time savings because of elimination of manual data entry of location of patients by staff and increased revenue of the hospital due to decrease in LWBS and increased number of returning patients because of better standard of care can be considered as quantitative returns for RFID tracking system. Proper management of available beds decreases the wait time of patients, speeds up throughput and hence decreasing the number of LWBS in ED which will increases the revenue as more patients will be seen every day. As RFID is automated patient tracking system, time and labor savings of personnel in ED will be increased enabling them to spend more time with patients and hence increasing standard of care of patients. This greatly affects staff satisfaction because of less labor and patient satisfaction because of better standard of care. Hence it decreases the number of diverts of patients to other hospitals and increases number of returning patients resulting into increased revenue of the hospital.]

9.2 ROI CALCULATIONS

Return of investment as defined earlier has both quantitative returns as well as qualitative returns. Qualitative returns cannot be computed and has to be assumed for proving its existence though quantitative returns that can be calculated. The quantitative returns are actual money flow to the organization. However, in healthcare industry it is very difficult to determine exact calculations without assumptions concerning quantitative returns. The result depends upon how the investment made on a implementing a new technology affects qualitative returns.

In the healthcare industry the profit directly depends upon the patients that come for treatment. By studying and observing the workflow in emergency department of UMMHC we determined some reasonable and acceptable assumptions for computing the projected hard returns. We conducted observational study twice in ED and measured the time taken by nurses or physician to change the status of patient every time patients are moved from one location to another. We measured the difference between time when the patient actually leaves the room after getting discharged and the length of time that the room shows up empty on Ibex system. The averages of this time are taken to calculate the hard returns incurred by timesavings. The detailed report of this observational study has been given in Appendix-4.

There are two factors that contribute to the quantitative return of investment. The major factor is the decrease in patients left without being seen (LWBS) per day and the other is the amount of time saved due to the automated tracking system facilitating the work of nurses and physicians. Both of these factors help create a more efficient workflow thus elevating the standard of patient care.

9.2.1 LWBS:

From our data, we determined a logical concept to determine the percentage decrease in LWBS number per year. We assume that most of the LWBS is mainly due to the waiting time. Patients get frustrated waiting beyond an hour or so, since that is a lengthy amount of time that gives them no other option but to leave the ED without receiving treatment. Other than frustration some patients have other reasons to leave such as commitments and those who consequently rather take care of themselves at home. Hence if the patient wait time is decreased, many LWBS patients can be captured from leaving. This could be achieved by efficiently managing capacity of ED. Below is the logical concept that we followed to determine the number of LWBS patients that we can capture by using RFID tracking system.

Data information of UMHHC

- Average patient per year = **75,000/year**
- Average patients per day = **235 patients/day**
- Average patients being admitted every day in main wing of hospital = **35 patients/day**
- Average discharge time (Average time difference between the empty status of room to show up on Ibex screen and the actual time the patient leave the room) = **10 minutes/patient**
- Average turn around of patient per bed every year = **950 patients/bed (BRISTOL GROUP RECORD)**
- Average LWBS/year seen at present stage = 2.3 % of 75,000 patients/year = **1725 patients/year**
- Average hospital collection per patient = **$350/patient**
- Average physician collection per patient = **$95/patient**

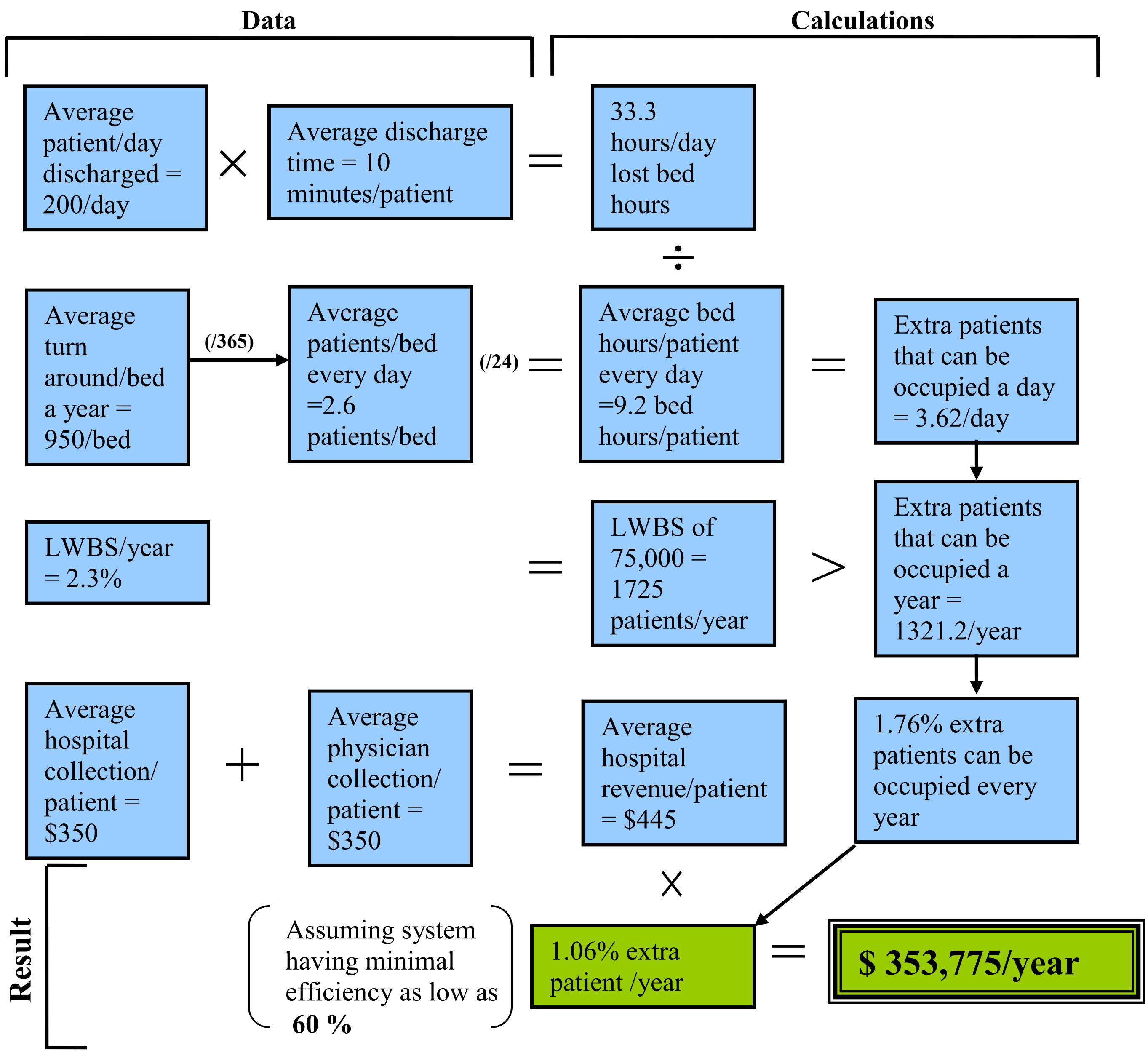


Figure 19: Returns incurred by counting number of LWBS captured on increasing throughput speed

On installing RFID tracking system bed management efficiency is increased greatly that will allow ED of UMMHC to capture left without being seen patients (LWBS). The number of patients that can be captured and hard return gained from them can be explained by a logical explanation and calculating number of factors affecting the decrease in LWBS. There is always a delay in showing room or bed empty on discharge of a patient, thus loosing bed hours. By multiplying average patients discharged per day (200 hr/day) to average delay in discharge time (10 min/patient) we get lost bed hour per day (33.3 hr/day). Average turn around/bed every year is 950 patients/bed which means every day 2.6 patients occupy a single bed giving result that every day a patients occupies a bed for average of 9.2 hours. We know 33.3 bed hrs/day are lost hence dividing it by an average number of hours occupied by a patient on a bed/day we can calculate extra patients that can be occupied in ED/day (3.62 extra patients/day). This on further calculations gives about 1321 extra patients can be occupied in ED every year that is 1.76% of total patients seen by ED every year. Among the total number of patients coming to ED 2.3% of patients leave without being seen giving hospital a loss of $445 for every single LWBS and this is mostly because of increased waiting period due to unavailability of rooms. By RFID tracking system we can minimize the waiting time by increasing capacity management efficiency and accommodating extra patients. We have already proven that by working efficiently we can see 1.76% of extra patients and if we assume RFID tracking system to have minimal efficiency of as low as 60% then we can capture 1.06% extra patients every year thus decreasing number of LWBS. Hospital revenue will increase by $445 with every extra single patient it can see which turns out to be $353,775/year if minimum of 1.06% patients are captured.

Calculations

- Average patients discharged every day from ED = 235 – 35 = **200 patients/day**
- Average patients occupied by a patient by a bed per day = 950 patients/365 days = **2.6 patients/day**
- Average time taken by a patient occupying a bed per day = 24 hours/2.6 patients = **9.2 hours/patient**
- Average bed hours lost per day = (200 patients*10 minutes) = 2000 min = 2000 minutes/60 minutes= **33.3 hours**
- Average extra patients that can be occupied per day without losing bed hours every day = 33.3 hours/9.2 hours = **3.62 patients/day**
- Average extra patients that can be occupied from the waiting area per year = 3.62 patients* 365 days = **1321.3 patients**
- Average percentage of extra patient that can be occupied every year = (1321.3*100)/75,000 patients = **1.76% /year**
- Average total revenue of hospital per patient = $350 + $95 = **$445/patient**

Results

As per the calculation we can easily capture 1.76% extra ED patients every year by making the throughput speedier in the ED. We need to consider that the proposed system cannot be 100% efficient. Thus we assume it to be a conservative 60% efficient. Thus we can capture 1.06% extra ED patients everyday. We have calculated the average revenue of hospital per patient hence the increased revenue by capturing minimum of 1.06% of patients' every year will be

- 1.06% of 75,000 = **795 patients/year**
- Revenue received from additional patients = 795 patients * $445 = **$353,775/year**

9.2.2 Time savings

Time savings cannot be quantified without making certain assumptions because the flow of patients at any point of time is constant and the number of times status changes occurred are the same for any two randomly selected patients in ED as they encounter different procedures and treatments. Hence, a necessary assumption has to be made for computing the amount of the time saved by not doing manual entry showing the location of patients. The assumptions here are made after doing an observational study of the workflow of ED. The smallest possible percentages has been considered. We have already discussed the scenario of a patient on arriving in ED in section 2.2.1. Considering our previous calculations, we can calculate the time saved. Below is the evaluation of the amount of time required to manually input the data in Ibex system per day. The figure below shows the change in status required for certain percentage of patients every day.

Observations

- Average patients seen in ED per day = **235 patients/day**
- Average time taken to change status and assigning room when in triage = **16.00 sec**
- Average time taken to change status for every movement inside ED = **7.00 sec**

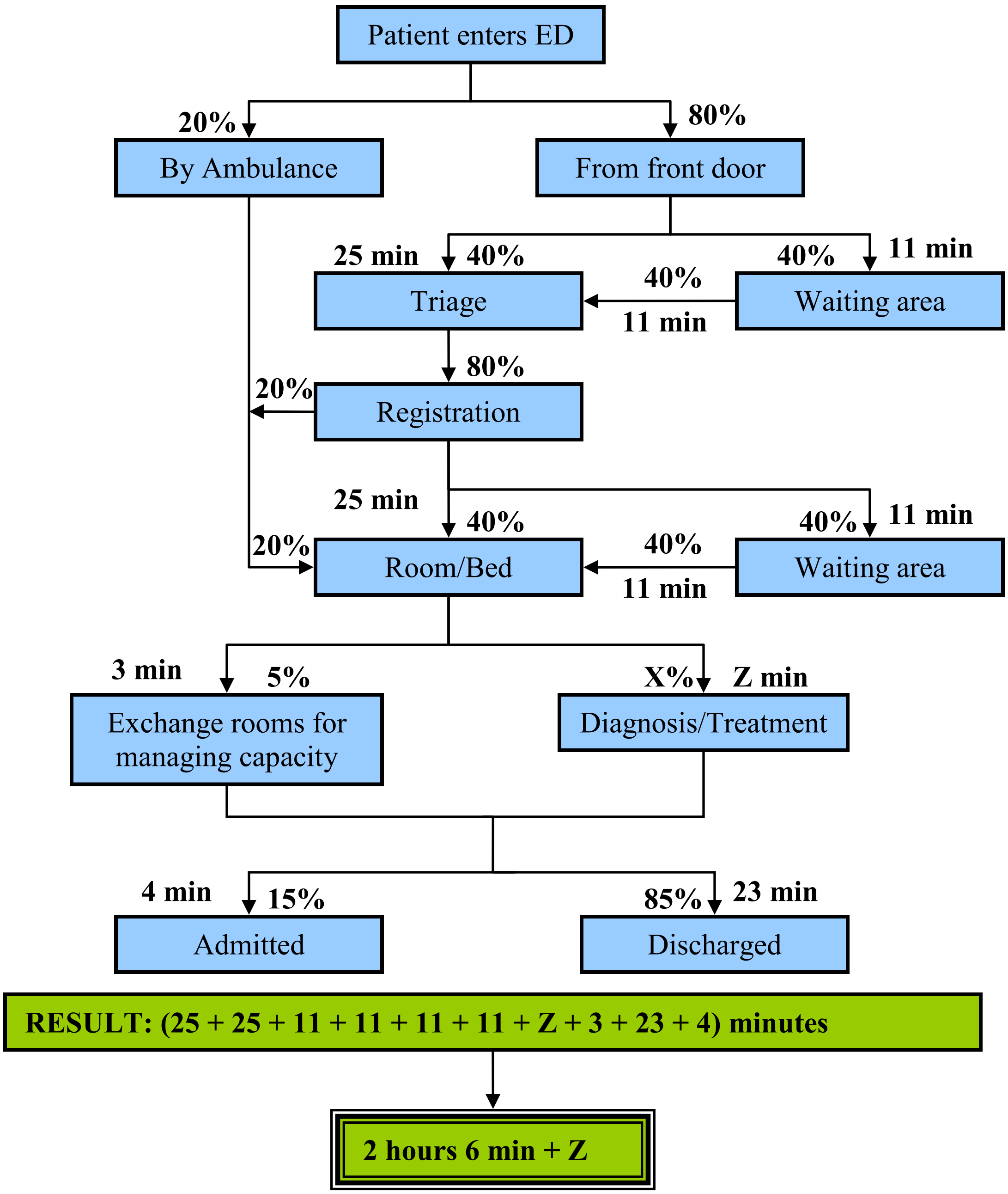


Figure 20: Amount of time spent every day for changing status of patients

The figure above shows the percentage of patients being moved to a certain location per day and time required to change their status upon every single change in their course of movement after entering into ED. The percentage of patients and time taken to change status is used from the result of the observational study done in ED of UMMHC (Appendix). Whenever every single patient is moved to one of the location listed above in the figure, the nurse has to change the status of the location of patients in order to keep track of them at any point of time. Depending upon the observations of the study this percentage of patients have been multiplied by relative time taken to change the status (7.05 seconds per one change) of all the patients per day whenever moved from one location to another. This time spent for changing status when summed comes out to be 2 hr 6 min + Z per day. This doesn't give hard returns directly but can be said to contribute greatly to labor saving, increasing staff satisfaction. Even staff can work more efficiently which in long run eliminates the need of hiring more staff in ED.

Assumptions and calculations

Everyday 20% of patients come to ED by ambulance and hence their status is directly changed to assigned room as soon as they enter and the registration goes to them for registering their information in Meditech. The calculation of time saved every time a status change occurs that is needed to be inputted manually during the course of movement of patient is as following

- Patients going to triage
    - Average number of patients going to triage right away = **40% = 94 patients/day**
    - Average number of patients going to triage after waiting in waiting room = **40% = 94 patients/day**
    - Average time spent for status change in triage= (94 + 94) * 16.0 sec = (25 + 25) minutes = **50 minutes**
- Patient going to waiting room before triage
    - Average number of patients = **40% = 94 patients/day**
    - Average time spent for status change = 94 * 7.0 sec = **11 minutes**
- Patients going to triage after waiting in waiting room
    - Average number of patients = **40% = 94 patients/day**
    - Average time spent for status change = 94 * 7.0 sec = **11 minutes**
- Patient going to waiting room after triage due to unavailability of room
    - Average number of patients = **40% = 94 patients/day**
    - Average time spent for status change = 94 * 7.0 sec = **11 minutes**
- Patient moving from waiting room to assigned room after triage
    - Average number of patients = = **40% = 94 patients/day**
    - Average time spent for status change = 94 * 7.0 sec= **11 minutes**
- Patient moved to other departments for diagnosis
    - Average number of patients = **X% = Y patients/day**

    - Average time spent for status change = Y * 7.0 sec = Z minutes
- Patient exchanged between room and hallway beds

  There are three shifts/day and 3 patients/shift are to be exchanged between room and hallway beds, which mean there are 6 status changes per shift for capacity management purposes. This is because when a patient in a room is exchanged with a patient already there in hallway bed or vice a versa there is a status change for both the patients. Therefore 12 patients are exchanged in a day that requires status to be changed 24 times/day.
    - Average number of patients = **5% = 12 patients/day**
    - Average time spent for status change = 12 * 2 * 7.0 sec= **3 minutes**
- Patient being discharged – status of the room assigned has to be changed to empty
    - Average number of patients = **85%** = **200 patients/day**
    - Average time spent for status change = 200 * 7.0 sec = **23 minutes**
- Patient being admitted – status of the room assigned has to be changed to empty
    - Average number of patients = **15% = 35 patients/day**
    - Average time spent for status change = 35 * 7.0 sec = **4 minutes**

Results

The total amount of time saved per day is

(50 + 11 + 11 + 11 + 11 + Z + 3 + 23 + 4) minutes = **2 hours 6 minutes + Z minutes/day**

Hence the total amount of time saved every year would be 365* =

This time saved does not give a direct hard return but is said to impact qualitative returns such as labor saving and increasing both staff and patient's satisfaction significantly because it decreases labor of staff and waiting time of patients respectively.

Time savings would widely affect the number of staff required in ED if the workflow is made more efficient and managed smartly in terms of capacity management. However considering the fact that ED of UMMHC requires more nurses and physician presently, if this technology is installed, in long run the necessity of hiring staff will not be required

any more and hence will save money for additional staff members. This in other terms can be said that it would save almost one FTE (Full Time Employment) per year.
However presently ED of UMMHC requires more staff so this savings can be taking into account on thinking that if this amount of time saved can avoid a nurse then fewer employees are required to work.

ROI:

The total amount of hard return that can be incurred on computing returns from LWBS = **$353,775/year**

The total cost of the system to be installed and additional cost for the first year is **=$179,051**

Hence after installation the system RI can met in **6 months 2 days**
≈ 6 months

Other than the parts mentioned above, there are additional ROI that are qualitative returns that are the most valuable resulting in improvement of operational workflow and satisfaction in ED.

9.3 POSSIBLE IMPROVEMENTS

Radio frequency identification is a technology that puts patients to a network, which enables others to detect their real time location. This improves communication, productivity & information in healthcare. Reports show an improved understanding of patient flow dynamics throughout this process. This knowledge can be used to drive facilities and process improvements that have a positive impact on efficiency, safety and quality of care that helps increase productivity. Real time information also prevents issues as RFID patient-tracking system contributes to various improvement possibilities that help increase revenue of a healthcare organization. The major possible improvements on using RFID for patient tracking within ED include:

- Operational Efficiency
    - Decreased patient Turn-around time
    - Improve workflow
    - Increase patient throughput
- Satisfaction
    - Staff satisfaction by reduced administrative tasks
    - Patient satisfaction by improved quality of care
- Benefits to hospital
    - Cost efficiency
    - Enhanced patient safety
    - Ensure Compliance and reduce risk exposure

9.3.1 Operational Efficiency:

Patient throughput and bed availability management are among hospitals top most concerns. By improving the patient flow continuum, patient throughput will increase. This can be achieved by proper management of the patient discharge process, which will decrease staff time in planning and assigning patients to beds and decrease the costs through alternative placement of patients when beds are not ready and available when needed. Patient tracking with RFID gives a real-time access, which greatly contributes to the optimization of patient throughput and improvement with patient and workflow. With the real-time status of every bed, combined with real-time status of every patient easily viewable on the Ibex system, hospital beds availability can be detected. This also allows Nursing, Admissions and the Emergency Department to more efficiently plan, manage and expedite patient flow, as well as help project clinical resource requirements necessary to provide proper patient care.

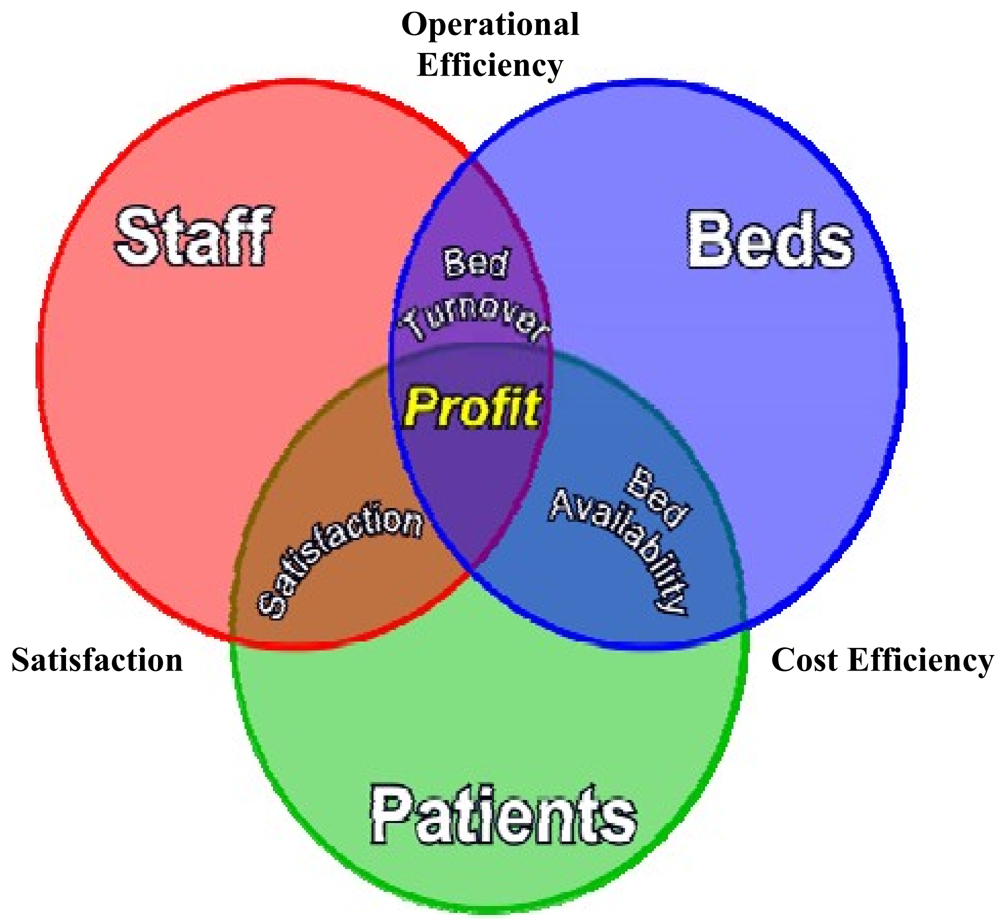


Figure 21: Improvements possible by implementing RFID tracking system

RFID tracking system contributes to the operational efficiency, satisfaction and cost of the ED. The three factors that mainly contribute to these improvements are staff, bed and patients. Operational efficiency is improved because of increased productivity and better notice of bed availability management, which improves patient and workflow in ED. This allows personnel manage more effectively, thus improving patient care in the process. As a result of this, patient satisfaction should increase since waiting time has decreased, along with the decrease of patients who are left without being seen. RFID tracking system enables automated update of patient location, which reduces staff labor and time spent inputting data manually into the Ibex system. This not only increases staff satisfaction but also adds to patient satisfaction as staff members have more time to spend with patients. All these improvements altogether influence the cost efficiency of the hospital. Due to effective utilization of beds more patients can be seen and decreases wait times eventually decreasing diverts of patients to other hospitals. Even with increased staff efficiency administrative cost is decreased, thus there is an increase in the revenue that means more profit.

Decrease Patient Turn-Around Time: The biggest complaint that patients have is the delay in getting in and out of the hospital when needing medical treatment. It is not uncommon in an emergency room situation to see multiple patients waiting not only for treatment but also to checkout the treatment have been performed. By utilizing RFID personnel are freed up from doing this entire manual imputing of data into the system and can see more patients, which results in higher overall satisfaction as well as decreased turn-around time for every patient seen.

Improved Workflow: RFID allows improving workflow through ED because of its better ability to track patients. Personnel are freed up from manual data entry and allowed to work with patients. Patients are tracked as they move throughout the hospital so that their healthcare is optimized and accurate. Both patients and personnel benefit from RFID technologies as it helps to not only track and record, but also alert and notify of any emergency felt by patient as the tags of Radianse has panic button on it that can be pressed anytime patient feels critical. This means a better overall patient experience and a streamlined process from check-in to checkout.

Increase Patient Throughput: As RFID helps to decrease the amount of manual tracking done by hospital personnel it also increases the throughput of patients thought the hospital. Interactive, real time bed management optimizes patient’s throughput.

9.3.2 Satisfaction:

Increased operational efficiency leads to both staff and patient satisfaction.

Staff satisfaction by reduced administrative task: Doctors and nursing personnel often spend more time on administrative tasks such as inputting patient’s location into Ibex system then they do dealing with patients directly. By implementing RFID technology within ED administrative tasks can be greatly eliminated and free up personnel to deal directly with patients while enhancing tracking process.

Patient satisfaction by improved quality of care: RFID tracking system provides the hospital with the ability to quickly increase bed availability by properly managing discharge process and decrease patient wait times. Faster bed availability and increased staff efficiency leads to higher satisfaction as well as improved quality of care for patients.

9.3.3. Benefits to hospital:

Using RFID for tracking patient benefits hospital to a great extent. As shown in earlier sections of Return of Investment increased revenue can be incurred on making the entire system efficient. In addition to it there is increase in patient safety with is the hallmark for any hospital.

Cost efficiency: Hospital executives are always looking for ways to maximize the bed resources in order to increase revenue while at the same time increasing patient satisfaction. It has been successfully derived that efficiently utilizing ED rooms and beds increases the throughput, and hence more patients can be seen every day. Increasing staff efficiency by saving time of manual data entry reduces administrative costs. Therefore, there is an accurate understanding of patient status and bed availability will dramatically decrease ED overcrowding and diverts of patients to other hospitals.

Enhanced patient safety: RFID tracking system is said to improve efficiency, but the main objectives in general healthcare however focuses on the welfare of patients in order to reduce medical errors and improve patient safety. Patient safety and accurate treatment are the hallmarks of any hospital. Identifying correct patients and ensuring they receive the proper treatment are foremost on the minds of every member of the hospital staff. With RFID technology patients can be identified and patient records of their movements can become a roadmap of their entire hospital stay as every movement is automatically logged. Medical errors are very extensive and expensive nowadays. And preventing them not only improves patient safety, but also reduces the risk of the hospital, physicians, nurses and other staff being exposed to lawsuits. Patients can be guaranteed accurate medical treatment as their entire stay can be tracked and recorded.

Ensure Compliance and Reduce Risk Exposure: RFID delivers unparalleled tracking capabilities as regulatory compliance can be handled automatically or with very little manual intervention needed. Hospitals reduce the risk of lawsuits when using RFID to track every aspect of hospital and patient management. Because if RFID tracking system is used for staff and patients then the RFID process can monitor and record patient and personnel interactions that can be used for both compliance and legal challenges.

Hence, implementing the RFID tracking system would produce much improvements and efficient workflow rather than create problems. For that to happen however, the staff must familiarize this system.

10.0 FUTURE RECOMMENDATION

RFID tracking has proven to be a viable tool in this project because of the short ROI incurred as well as cost incurred each year after. Also there are little or no disadvantages after implementing the project, which makes business more efficient. Apart from the hard returns, other profits and benefits to the hospitals, patients and staff can also be seen as mentioned above along with benefits for other applications. This technology can be recommended for future expansion in a health care organization for applications such as staff and equipment tracking.

- **Equipment tracking**: The same technology can be integrated for tracking of equipments such as infusion pumps, EKGs, gurneys, ventilators, portable x-ray machines, wheel chairs, etc. In ED it is not affordable to spend precious time looking for equipments because of its busy nature. Even tracking equipments would give accessibility to any equipment at any particular time hence making better utilization of the assets and avoiding cost of buying extra equipments to match up with the rush in ED.
- **Staff tracking**: It was witnessed in the observational study done in UMMHC-ED that most of the staff members look for each other most of the time creating panic and confusion. Hence by integrating PDA devices with the existing tracking system it would become easier to locate another nurse, physician or doctors and save a lot of time which can be utilized in treating more patients. Thus this will help in adapting a workflow for better resource utilization.

These tracking systems can be later expanded in the entire hospital for better efficient system and workflow. Besides patients, staff and equipment tracking there are other different type of tracking that can be carried out for safety purposes of patients.

- **Infant tracking:** This technology can be helpful in reducing the errors of matching up the babies with the parents. It will track location of infant accurately in case of them getting stolen.
- **Medicine and drug tracking:** This technology can avoid counterfeit of drugs which presently a big issue. Also if patients will specific allergies are given some drugs by mistake, which can be dangerous to patient this technology will start an

alarm warning staff. Hence this will provide patients an additional safety from medical errors.

We strongly recommend implementing this technology throughout hospital and use it for different applications to earn more savings. Combining all these tracking systems into one technology will dramatically give more profits and benefits in long run for any hospital.

10.0 CONCLUSION

In summary this report abundantly confirms the deficiencies and limitations of the current patient tracking system employed in the Emergency Department of the UMMHC. Implementation of an RFID patient tracking system will dramatically decrease the number of patients left without being seen by improving the work flow and capacity management. This will be a new source of revenue for the hospital. Implementation of this patient tracking system will also lead to a higher patient and staff satisfaction. An increased number of returning patients, time and labor saving are the other advantages of this system.

As a result of precise computations and observational studies, the proposed cost of this tracking system is calculated. It is estimated that the full return on investment will be achieved in about 6 months after installation. Therefore, taking advantage of the RFID patient-tracking system is highly recommended by our team. Future extension of RFID to equipment and staff tracking is also suggested although these areas were not the targets of this project.

REFRENCES:

[1]Jonathan Collins, "Rfid remedy for medical errors" RFID Journal, 6/15/2006.

Source: http://www.rfidjournal.com/article/articleprint/961/-1/1/

[2]Shang-Wei Wang, Wun-Hwa Chen, Chorng-Shyong Ong, Li Lui, Yun-Wen Chuang. "RFID applications in hospitals: a case study on a demonstration RFID project in a Taiwan Hospital," IEEE - Proceedings of the 39th Hawai International Conference on System Sciences, 5/2006, Hawaii, pp. 1-10.

Source: http://doi.ieeecomputersociety.org/10.1109/HICSS.2006.422

[3]Raghvinder S. Sagwan, Robin G.Qui, Daniel Jessen. "Using RFID tags for Tracking patients, Charts and Medical Equipment within an Integrated Health Delivery Network". 7/2005.

Source: http://ieeexplore.ieee.org/Xplore

[4]"The history of RFID technology,"
http://www.rfidjournal.com/article/articleprint/1338/-1/129/.

[5]Melanie R. Rieback, Bruno Crispo, and Andrew S. Tanenbaum. "The Evolution of RFID Security", IEEE CS (Computer Society) and IEEE ComSoc (Communications Society) – Pervasive Computing, January-March 2006, pp. 62-69.

Source: Pervasive Computing, January-March 2006 Issue

[6]"ABCs of RFID: Understanding and using radio frequency identification", White Paper of Intermec Inc., 01/2006.

Source: http://www.bitpipe.com/detail/RES/1140197703_741.html

[7]Cheng-Ju, Li Liu, Shi-ong Chen, Chi Chen Wu, Chun-Huang Huang, Xin-Mei Chen. "Mobile Healthcare Service System Using RFID," IEEE – Proceeding of 2004 IEEE, Conference on Networking, Sensing and Control, 9/2004, Taipei, Taiwan, pp. 1014-1019.

Source: http://ieeexplore.ieee.org/Xplore/

[8]Klaus Finkenzeller, "RFID Handbook: Fundamentals and Applications in Contact-less Smart Cards and Identification". John Wiley and Sons, Second Edition, 2003.

[9] Steven Shephard, "RFID : Radio Frequency Identification", McGraw Hill, 2005

[10]" The Basics of RFID technology", http://www.rfidjournal.com/article/articleprint/1337/-1/129/ .

[11] "RFID systems components and costs", http://www.rfidjournal.com/article/articleprint/1336/-1/129/ .

[12]Madhav Pappu, Rohit Singhal, Ben Zoghi. "RFID in Hospitals: Issues and Solutions," Consortium for the accelerated Deployment of RFID in Distribution, September 2004, pp. 1 – 12.

[13]Roy Want. "An introduction to RFID technology", IEEE CS (Computer Society) and IEEE ComSoc (Communications Society) – Pervasive Computing, January-March 2006, pp. 25-33.

Source: Pervasive Computing, January-March 2006

[14] Martin O'Halloran, Martin Glavin. "RFID patient tagging and Database System", IEEE – Proceedings of the International Conference on Networking, International Conference on Systems andInternational Conference on Mobile Communications and Learning Technologies (ICNICONSMCL'06), 2006.

Source: http://ieeexplore.ieee.org/Xplore/

[15] RFID Systems", http://www.rfidasia.com/htmdocs/rfid_systems/systems.htm

[16]Won Jay Song, Sang H. Son, Munkee Choi, Minho kang. "Privacy and Security Control Architecture for Ubiquitous RFID Healthcare System in Wireless Sensor Networks", IEEE, 3/2006, pp. 239 – 240.

Source: http://ieeexplore.ieee.org/xpl/

[17] "RFID standards", http://www.rfidjournal.com/article/articleprint/1335/-1/129/

[18]Badri Nath, Franklin Reynolds, Roy Want. "RFID technology and Applications", IEEE CS and IEEE ComSoc – Pervasive Computing, January-March 2006, pp. 22-24.

Source: Pervasive Computing, January-March 2006

[19] http://www.vixia.com/

[20]"RFID: Coming to a Hospital near You." Sun Microsystems Press, April 2004

Source: http://www.sun.com/solutions/documents/articles/HC_rfid_aa.xml

[21]"RFID: Cure for Counterfeit Drugs." RFID journal, 10/15/2003.

Source: http://www.rfidjournal.com/article/articleprint/611/-1/1/

[22]Melanie R. Rieback, Bruno Crispo, Andrew S. Tanenbaum, "Is your cat infected with a computer virus", IEEE Percom (Pervasive Computing), 2006.

[23]Mike Dempsey, "Analyzing the Return on Investment for Indoor Positioning Systems", White Paper of Radianse Inc., 12/2004.

Source: Radianse Inc. 439 South Union Street Suite 403, Lawrence, MA 01843

[24]"Radio frequency identification (RFID)", White Paper of Accenture, 11/16/2001.

Source: http://whitepapers.zdnet.co.uk/0,39025945,60029591p,00.htm

Appendix – 1

GLOSSARY

AID – Automatic Identification

ECG/EKG - Electrocardiogram

ED – Emergency Department

EM – Electromagnetic

EPCglobal – Electronic Product Code Global

EPROM – Electronically Programmable Random Access Memory

ER – Emergency Room

ERP – Electronic Road Pricing

FDA – Food and Drug Association

HF – High Frequency

HIS – Healthcare Information System

IC – Integrated Circuit

IEEE – Institute of Electrical and Electronics Engineers

ISO – International Standards Organization

LAN – Local Area Network

PLC – Programmable Logic Circuit

RAM – Random Access Memory

RFDC – Radio Frequency Data Communication

RFID – Radio Frequency Identification

RLTS – Real Time Location System

ROM – Read Only Memory

UHF – Ultra High Frequency

UMMHC – UMass Memorial Health Center

WLAN – Wireless Local Area Network

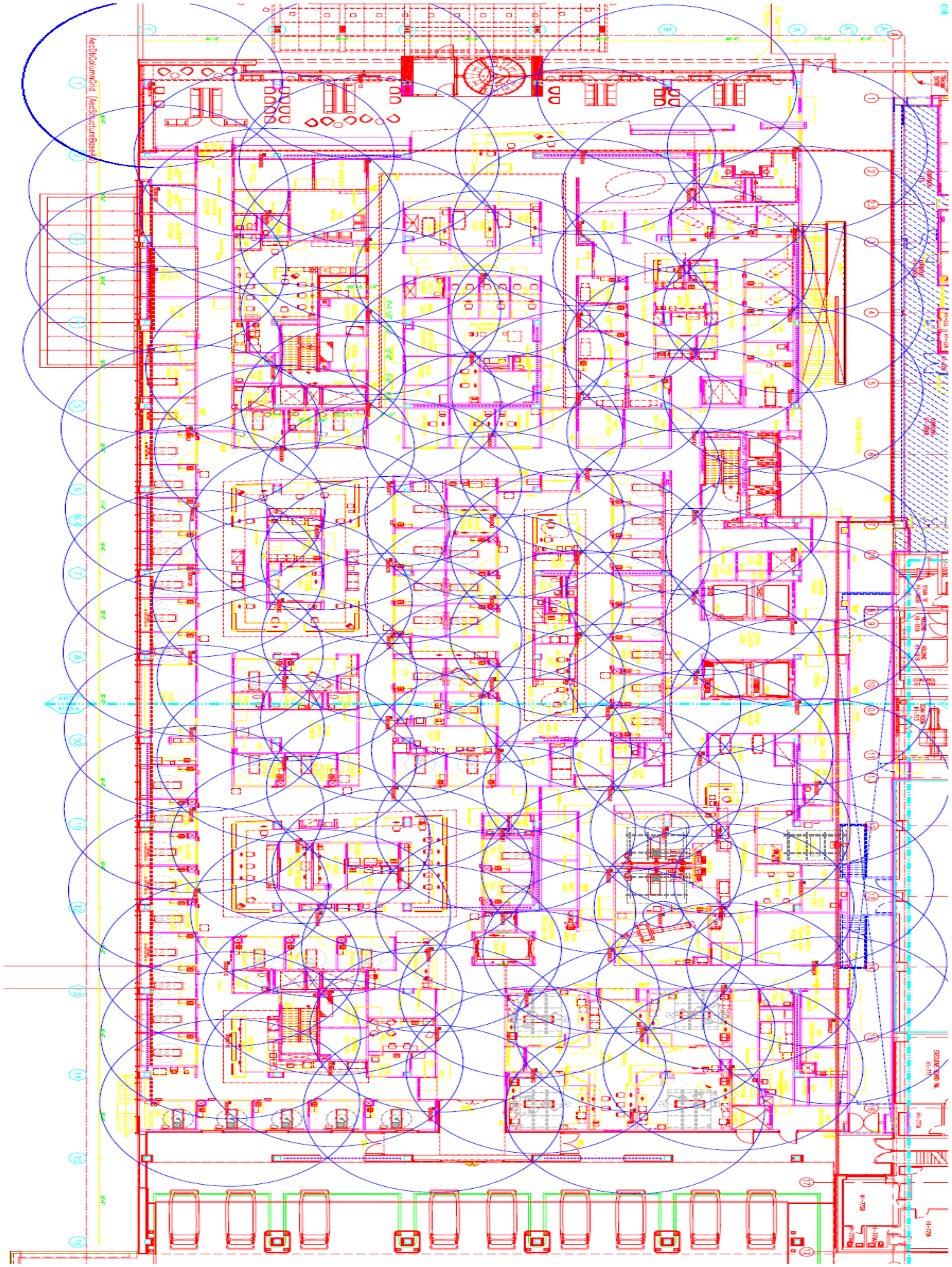
APPENDIX – 2

ABOUT RADIANSE INC.

Radianse, a company located in Lawrence, Massachusetts was founded in 2001, provides indoors-global positioning system (IPS) for tracking of patients in hospitals. It is a company that invented IPS and is marketing for the medical industry. Although IPS technology was first used to track equipment and prevent asset loss, it was later developed for tracking patients and staff locations at hospitals to optimize the workflow in real time, including the waiting time and availability of each bed. Focusing on the healthcare environment, Radianse combines infrared and radio frequency transmissions for transferring data, using software and receivers, along with web enabled devices to provide the precise location. This is used for any medical device or personnel outfitted with a small, battery-powered transmission tag. Since receivers' use Ethernet wiring and connection to existing networks, the application is installed with ease and uses little bandwidth. Each receiver collects its data from a 30-foot radius in complementation with the hospital's server and Radianse's software, which makes the location and information available through all desktops and PDAs through a Web interface. Multiple receivers may also be paced throughout the hospital for maximum tracking coverage, which is analogous to a cell phone transmitting in areas. The IPS is an open system and does not interfere with medical equipment and current existing hospital information systems that use wireless technology. In addition to that, using IPS during busy hours at the hospital would be much beneficial as doctors can retrieve information immediately from the information systems network. To address privacy issues regarding the Radiance IPS, the patient is given user control to turn off the tracking.

Radianse is approved by the Federal Communications Commission (FCC) and was released in the U.S. market during November 2003. In addition to being used by the ORF program, the Radianse IPS is also beta tested at several European hospitals and the company launched it internationally in early 2004. This technology costs $8 to $30 for each tag, depending on its security features and battery life. The list price for a receiver is $350. Radianse also has a number of partners that includes GE healthcare, WELCH ALLYN MEDICAL PRODUCTS, PICIS, PREMISE and many more to incorporate the IPS into existing technology. Radianse is one of the few suppliers that generated good recognition in the market with 16 hospital customers, including Massachusetts General Hospital, Boston. They are also leading the way with accurate, affordable and practical applications to improve asset management, clinical workflow and patient tracking.

APPENDIX – 3



ED FLOOR MAP AND SITES OF INSTALLATION OF READERS

APPENDIX – 4

OBSERVATIONAL STUDY REPORT:

To determine the inefficiencies and the weak points of the current tracking system, we carried out an observation inside the emergency department of the UMMHC. We did the experiment twice as a team in a normal business day inside the ED's North Pod, South Pod, Pediatrics department, front desk and triage. We mainly focused on tracking the amount of time spent to either enter or edit the data manually into the Ibex and meditech during the different phases of treatment while the patient's status is changed.

Table 9: Observations of time take to change the status of patient in different situations

	Time taken to change the status of the patient in ED (sec)						
Observations	I	II	III	IV	V	VI	**Average**
Registration into greeter of Ibex	14.04	16.75	18.41	21.34	15.03	21.19	13.345
Triage	11.28	21.62	13	18.09	9.62	22.75	16.06
Change in status	6.5	5.6	7.43	8.23	7.47	-	7.05
Adding a comment	12.03	20.42	13.43	14.71	-	-	15.1475
Delay in discharge	8.05	10.23	15.34	5.89	12.64	-	10.43

As shown in the table above different changes occur during course of movement of patient right from admission to discharge. First the patient's name, gender, age and chief complaint is registered into the ibex greeter. The average time required to register a patient is 13.345 seconds. When a patient is taken to triage the patient undergoes various primary diagnosis procedures and their status is changed to "triage completed" and necessary other status change like "the assigned room number" or "in the waiting area", which takes about 16.06 seconds on an average. Now the patient is entered into the ED if there is availability of room or into waiting area. After entering into the room patient is moved around for different diagnosis or treatment reasons. Sometimes patients in hallways and rooms switch their positions depending upon the urgency of their treatment. All of this status change has to be entered into the Ibex system for other staff members to locate the patient at any given time and time take for such status change is about 7.05

seconds on an average. All of these observations will help greatly in time saving if an automated tracking system is employed in a hospital environment. The main factor that will help in return of investment of RFID tracking system is delay in discharge time. This is the time difference between the time the patients leaves the room after being discharged and the time at which that respective room's status shows up "Empty" on the Ibex tracking system. According to the observational study done there is a huge delay for this information to show up, which not only misguides staff about the whereabouts of the patients but also increases the waiting period of incoming patients. It was observed that the average delay in discharge time is 10.43 seconds. The amount of time taken for these delays and status changes increases in rush hours as staff is too busy to change the status in real time. Hence this observational study is more effective on a very busy day of ED.

Apart from the record of time for such status changes we also recorded any other problems that we observed related to the Ibex system. We can summarize the problem scenarios into 6 main categories.

1. Nurses are spending their valuable time searching for the patients. They have to call another staff using VOCERA to ask for the patient's location. They not only get frustrated and spent a lot of time looking for the patients, but also take the other staff's time.
2. Some of the staffs are unwilling to use the Ibex system, since they believe everything can be done by paper work. Some ask each other instead of using the tracking system.
3. Others don't have enough time to record every single status change or update the comments which leads to confusion and unprofessional capacity management. For example, Most of the time nurses don't change the status of the patient when they move to X-Ray Room since they are returned to their room shortly. But this can play a major role if the status is change for that short period of time. For example, a patient can be diagnosed by a doctor in that short period in that patient's room hence very effectively contributing to capacity management.
4. There are some situations were patients are reluctant to stay in the ED and actively try to run away from their rooms. In one case, although the physician and

the nurse tried to keep him in sight, he managed to get out of the room until the security came into action. Such patients may be wondering around. They can not be tracked easily and that can cause troubles for the hospital.

5. There are usually some food trolleys lying in the hallway waiting carrying what is served to the patients. While the patients are assumed to be in their room, they are usually in another department like x-rays or radiology. The ED is one of the busiest department and the hallways need to be open for staff and patient to freely move around and do their job.
6. If the nurses are asked to update or change the status, it is hardly even close to real time since their busy schedule does not allow them to do so. A patient was discharged from one room and a new patient was assigned to it. Since the nurse failed to provide the information to the Ibex secretary, the previous patient was shown on the screen for more than 20 minutes. This is a clear example of delay in discharge time which can be even more than 20 minutes in some cases.

Thus there several issues were encountered regarding the tracking of patients in ED, which if looked upon suggest losses in terms of time, patients and both staff and patients satisfactions. The data from this observations study is utilized to compute the return of investment for RFID tracking system.

APPENDIX – 5

MASS GENERAL REPORT

According to the senior project manager at UMass Memorial health center, Mr. John McGowens, a comparison could not be made between the RFID implementation at Mass General hospital and the emergency department at UMass. This is due to the fact that Mass General only uses RFID in their operating rooms, which is a much easier process as they will know who and where the RFID tags are assigned to (since surgery is pre-planned). In our case however, we are trying to implement this system to the whole emergency department, which will most likely require much more time for adaptation and getting used to the new procedure may be tricky.

At Mass General hospital, 54 operating rooms are tracked by RFID, using a quadrant tracking system. Implemented in the year of 2003, they planned to use this tracking system more of a research tool designed to test the movement of in and out patients, rather than an actual capital investment, although it is in consideration. This is much flexible for Mass General as they are backed by huge amount of funds where in UMass Memorial health center is limited. The procedure of assigning and retrieving a RFID tag is much easier since the staff would know when exactly the patient is getting the tag, and where the patient will be at that certain time; since they are in need of an operation. This could not be said for UMass, as they would never know when or where these tags could be assigned and located.

Some of the unexpected costs at Mass General include mainly the loss of tags that are mostly left outside the building, along with infection control costs where dust must be removed in all operating rooms to maintain a safe and sanitary environment. Also, due to the fact that Radianse uses infrared, it may be hard at times to determine which side of a wall a patient is located in. Some possible solution to this may be placing readers in high locations near the ceiling to gain better line of sight. The implementation and installation took about a few weeks and about one to seven days for the workers to get used to the system, mostly because of the problems regarding the tracking grid. Staff tracking however was not used since the workers are not unionized. Therefore, we do not know the benefit of staff tracking using RFID.

In the financial aspects of RFID implementation, a cost of around 250,000 dollars to 400,000 dollars could be expected. However, after spending so much money, there is hesitation regarding the return of investment, because they do not know if it would increase revenue or decrease cost to raise profit. Indications that Mr. McGowens has pointed out is the possibility of reducing a nurse during a shift, but other than that, it is just merely productivity enhancement for the staff members in the working environment.

Maintenance of the system and its components also costs the hospital money. If reusable RFID tags were used, they would have to be cleaned every day at certain hours to ensure that they have enough for incoming patients. Currently at UMass Memorial health center, they have approximately 10% of VOCERA communication devices in reserve for the staff, but for RFID however, 50% of reserves may be expected in case of busy hours. System upgrades and maintenance is also required, which usually costs around 1000 to 2000 dollars each year. But the main cost that could be dealt with is the loss of RFID tags. This would not be a problem if disposable tags were used every day, however would cost much more at 10 dollars each with regards to 75,000 patients a year. A solution to reducing the loss of tags is the installation of security doors that cost a maximum of 5000 dollars each door; however, it is not guaranteed that after the alarm rings, the tag will be obtained back from the patient whose leaving. Other problems may include the loss of electricity and the downtime procedure. The downtime procedure is six seconds and then will use light boards as their source of electricity, which should not be a huge issue if RFID tracking was implemented.

One possible improvement that Mr. McGowens stated is the display technology that Radianse provides. The grid, also known as a display map, is not very clear to many staff members at Mass General, as they would like to see a more interactive map. Other than that, Mass General is very much considering the implementation of this technology in other parts of the hospital, as they have been much more efficient with capacity management as a result of RFID.

At UMass memorial health center, we believe that if RFID were implemented, the number of patients left without being seen would decrease significantly. If it were to decrease by at one percent from an average of two and half, much of the lost revenue would be made up, thus, more profit will be gained as a result.